PB82-227497

Water Reclamation and Automated Water Quality Monitoring

Boeing Co.
Huntsville, AL

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Mar 82

U.S. Department of Commerce
National Technical Information Service
NTIS

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"

EPA-600/2-82-043
March 1982

PB82-227497

WATER RECLAMATION AND AUTOMATED WATER QUALITY MONITORING

by

E. L. Jeffers, R. L. Brooks, D. Nibley,
J. D. Poel, J. Perreira, R. H. Nuss
The Boeing Company
Houston, Texas 77058

and

K. Nishioka
NASA Ames Research Center
Moffett Field, California 94035

and

W. J. Sanchez, Jr., D. F. Kriege
Santa Clara Valley Water District
San Jose, California 95118

Interagency Agreement No. AD-80-F-0-054-0

Project Officer

John J. English
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

REPRODUCED BY
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)

TYPING GUIDE SHEET

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-82-043	2. ORD Report	3. RECIPIENT'S ACCESSION NO. PB82 227497
4. TITLE AND SUBTITLE WATER RECLAMATION AND AUTOMATED WATER QUALITY MONITORING		5. REPORT DATE March 1982 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) W. J. Sanchez, Jr., D. F. Kriege, E. L. Jeffers, R. L. Brooks, D. Nibley, J. P. Poel, J. Perreira, R. H. Nuss, K. Nishioka		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Boeing Company 1300 Bay Area Blvd. Houston, Texas 77058	NASA AMES Res. Ctr. Moffett Field, California 94035 Santa Clara Valley Water Dist. 5744 Almaden Expressway San Jose, California 95118	10. PROGRAM ELEMENT NO. AZB1B DU B-113 11. Interagency EPA Agreement #AD-80-F-0-054-0
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory - Cin., OH Office Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final, 7/80 - 9/81 14. SPONSORING AGENCY CODE EPA/600/14
15. SUPPLEMENTARY NOTES Project Officer: John N. English, Phone: 513/684-7613		

16. ABSTRACT

The Santa Clara Valley Water District owns and operates a water reclamation facility located in the Palo Alto Baylands area in Northern California. The purpose of the facility is to provide reclaimed water suitable for injection into the groundwater, thereby providing a salt water intrusion barrier and, secondarily, to provide a research facility for various ongoing projects. The project results reported here involved using the NASA Ames Research Center's Water Monitor System to collect data on the water reclamation process train. The Water Monitor System is a continuous on-line water quality monitoring system which automatically measures 14 water quality parameters in addition to 9 trace halocarbons. The system was built and operated by Boeing Aerospace personnel through a contract with the NASA. For a period of three and one-half years, the system has gathered information on water quality changes at intermittent points throughout the treatment process train. This report presents the results for the last 8-month period, including performance and costs of operation for both the Water Reclamation Facility and the Water Monitor System. These results, especially for the water treatment processes, may be unique to this facility and should be interpreted cautiously.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Wastewater reuse Water quality monitoring Water reclamation Advanced wastewater treatment Wastewater process control Instruments Digital computers Automatic control, Data processing	Total coliforms, Metals Halocarbons, Trace Organics, Potable Waters, Nutrients, Groundwater Injection	13B
18. DISTRIBUTION STATEMENT Release to public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 216
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77)

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and Government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater, solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes the results of an 8-month test program to determine the performance and operating/maintenance costs of (1) an advanced wastewater treatment plant designed to reclaim up to 0.09 m^3/s (2 mgd) of wastewater for reuse and (2) an automated instrumentation system for monitoring and quality control of the treated water.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

The Santa Clara Valley Water District owns and operates a water reclamation facility located in the Palo Alto Baylands area in Northern California. The purpose of the facility is to provide reclaimed water suitable for injection into the groundwater, thereby providing a saltwater intrusion barrier and, secondarily, to provide a research facility for various ongoing projects. One specific project involves the NASA/Ames Research Center Water Monitor System, a continuous online water quality monitoring system which measures fourteen water quality parameters in addition to nine trace halocarbons. The system was built and operated by Boeing Aerospace Company personnel through a contract with the NASA/Ames Research Center. For 3 1/2 years, the system has been gathering information on water quality changes at intermittent points throughout the treatment process scheme. This report presents the results of an 8-month program to determine the performance and costs of operation for both the Water Reclamation Facility and the Water Monitor System.

The following conclusions relative to process performance are based on the Water Monitor System (WMS) data:

a. Chemical clarification removed over 90% of the influent suspended solid (biomass) and as much as 30% of the organic contaminants (TOC).

b. Except for some reduction in trace of halocarbons and biomass, the contribution of ozone to water quality, at the concentrations used in this study, does not appear to be significant.

The capability to collect and process data for convenient and improved analysis of water quality information has been demonstrated. Over three million water quality measurements were recorded during the test period and are summarized in this report. Both the reclamation facility and the water monitoring system were designed and constructed as experimental test beds where reliability was of a secondary importance to flexibility. Neither system was intended to function as an operational system. Rather, they were intended for testing various concepts and configurations for advanced wastewater treatment, automated water quality monitoring, and process control. Consequently, the numbers quoted in this report for availability and reliability are not representative of the performance that should be expected from operational systems. This experience should help to guide the future design of reliable operational systems.

This report was submitted in fulfillment of EPA Agreement No. AD-80-F-0-054-0 by the National Aeronautics and Space Administration, The Boeing Company, and the Santa Clara Valley Water District, under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period of July 1, 1980 to February 28, 1981, and was completed August 1, 1981.

CONTENTS

Foreword iii
Abstract iv
Figures ix
Tables xii
Acronyms xiii

1. Introduction 1
    SCVWD-WRF/PA (Santa Clara Valley Water District-Water Reclamation Facility at Palo Alto) Background 1
    WMS (Water Monitor System) Background 1
    Test Program 2
    Test Objectives 2

2. Conclusions 5

3. Recommendations 8

4. WMS 10
  Description 10
    General 10
    Utilities 10
    Sample Collection and Distribution System 10
    Total and Viable Biomass 13
    Total Residual Chlorine 19
    Turbidity 19
    Dissolved Oxygen 20
    Total Organic Carbon 20
    Ammonia 22
    Nitrate/Nitrite 22
    pH 22
    Conductivity 22
    Temperature 22
    Hardness 22
    Sodium 23
    Gas Chromatograph 23
    Total and Fecal Coliform 26
    Data Acquisition and Report Generation System 33
Performance Evaluation 38
    Sample Collection and Distribution System 38
    Chemiluminescence Biosensor 39

Preceding page blank

Gas Chromatograph 41
Total Organic Carbon Analyzer 41
Hardness Analyzer 42
Nitrate Analyzer 42
pH Analyzer 42
Total Residual Chlorine Analyzer 42
Sodium Analyzer 43
Temperature Analyzer 43
Turbidity Analyzer 43
Coliform Detector 43
Ammonia Analyzer 45
Conductivity Analyzer 46
Dissolved Oxygen Analyzer 46
Deionized Water System 46
Data Acquisition and Report Generation System 46
WMS Availability 47
WMS Reliability 47
WMS Operations and Maintenance Costs 47
Summary 52
Data Processing 53

5. SCVWD-WRF/PA 62

Description 62
General 62
Control and Instrumentation 62
Chemical Clarification 64
Recarbonation 66
Mixed-Media Filtration 66
Ozonation 67
Granular Activated Carbon Sorption 67
Plant/Process Performance Evaluation 67
Input/Output 69
Plant/Process Availability 101
Plant Reliability 103
Plant O&M Costs 103

6. Future Applications 109

References 112

Appendices

A Statistical Analysis Coefficients 114
B Stanford/WMS Data for Organics Removal by GAC 158
C Plant Downtime and Maintenance Log 181
D WMS Costs 190

FIGURES

NUMBER		PAGE
1	Water Monitor System Configuration	11
2	Sample Collection and Distribution Flow Schematic	14
3	Biosensor Calibration Curve for Total Bacteria	15
4	Biosensor Response Versus Viable Bacteria	16
5	Chemiluminescence Biosensor Flow Schematic	18
6	Total Organic Carbon Sensor Flow Schematic	21
7	Automated Gas Chromatograph Water Analysis System Flow Schematic	24
8	Coliform Sensor Flow Schematic	27
9	Coliform Sensor Calibration-Fecal Coliform	31
10	Coliform Sensor Calibration-Total Coliform	32
11	WMS Computer System	35
12	ADAM System Configuration	36
13	EVE System Configuration	37
14	Total and Viable Bacteria Levels in Various Wastewater Effluents	40
15	Santa Clara Valley Water District Reclamation Facility at Palo Alto	63
16	Sampling Schedule	70
17	Data Distribution and Process Removal Characteristics - Total Biomass	73

18 Data Distribution and Process Removal Characteristics - Viable Biomass 74

19 Data Distribution and Process Removal Characteristics - Total Organic Carbon 75

20 Data Distribution and Process Removal Characteristics - Turbidity 76

21 Data Distribution and Process Removal Characteristics - Total Residual Chlorine 77

22 Data Distribution and Process Removal Characteristics - Dissolved Oxygen 78

23 Data Distribution and Process Removal Characteristics - Ammonia 79

24 Data Distribution and Process Removal Characteristics - pH . . . 80

25 Data Distribution and Process Removal Characteristics - Conductivity 81

26 Data Distribution and Process Removal Characteristics - Hardness 82

27 Data Distribution and Process Removal Characteristics - Total Halocarbons 83

28 Data Distribution and Process Removal Characteristics - Trihalomethanes 84

29 Data Distribution and Process Removal Characteristics - Tetrachloroethylene 85

30 Data Distribution and Process Removal Characteristics - Methylene Chloride 86

31 Data Distribution and Process Removal Characteristics - Chloroform 87

32 Data Distribution and Process Removal Characteristics - Trichloroethane 88

33 Data Distribution and Process Removal Characteristics - Bromodichloromethane 89

34 Data Distribution and Process Removal Characteristics - Trichloroethylene 90

35 Data Distribution and Process Removal Characteristics - Dibromochloromethane 91

36 Data Distribution and Process Removal Characteristics - Bromoform 92

37 Time History of Granular Activated Carbon Performance 100

38 Determination of Reliability 104

39 Relationship Between Cost and Reliability for Complying with COD Discharge Limit by Granular Activated Carbon Regeneration . . . 108

xi

TABLES

NUMBER PAGE

1 Reliability of Palo Alto Reclamation Facility 3

2 WMS Sensors 12

3 Biosensor Hourly Schedule 19

4 Coliform Sensor Schedule 29

5 Comparison of Coliform False Positives 45

6 WMS Availability/Reliability Summary 48

7 WMS Cost Summary 50

8 Sample Statistical Data 60

9 Sample Regression Analysis 61

10 SCVWD-WRF/PA Unit Process Characteristics 64

11 Plant Instrumentation 66

12 Process Configurations for Test Periods 68

13 Plant Performance for Two Test Periods 71

14 Process Performance for Two Test Periods 72

15 Chi squares of Process Effluents for Two Test Periods 94

16 Significant Changes in Normal Distribution Across Processes . . 96

17 Availability of Palo Alto Reclamation Facility 102

18 Operations and Maintenance Costs of Palo Alto Reclamation Facility 104

19 Estimated Costs and Savings for Automated Instrumentation . . . 110

ACRONYMS

A/D	Analog to Digital Converter
ADAM	Air Data Acquisition and Monitoring
AER	Aeration
ATP	Adenosine Triphosphate
b	Constant
BOD	Biochemical Oxygen Demand
BV	Biosensor Valve
C	Concentration
$CaCO_3$	Calcium Carbonate
C_2CL_4	Tetrachloroethylene
CHLOR	Chlorination
CLAR	Clarification
CH_2Cl_2	Methylene Chloride
$C_2H_2Cl_2$	1,2 - Dichloroethylene
$CHCl_3$	Chloroform
CH_3CCl_3	1,1,1, - Trichloroethane
$CHBrCl_2$	Bromodichloromethane
C_2HCl_3	Trichloroethylene
$CHBr_2Cl$	Dibromochloromethane
$CHBr_3$	Bromoform
CLSS	Closed-Loop Stripping System
CO	Carbon Monoxide

COD	Chemical Oxygen Demand
$^{\circ}C$	Degrees Celsius
CRT	Cathode Ray Tube
CV	Coliform Valve
DAS	Data Acquisition System
DI	Deionized Water
DO	Dissolved Oxygen
DOY	Day of Year
DSLTB	Double Strength Lauryl Tryptose Broth
ECD	Electron Capture Detector
EDTA	Ethylene Diamine Tetra Acetic Acid
EVE	Environmental Verification and Evaluation
$^{\circ}F$	Degrees Fahrenheit
FID	Flame Ionization Detector
FILT	Filtration
floc	Flocculant
GAC	Granular Activated Carbon
GC	Gas Chromatograph
GLI	Great Lakes Instruments
gm, gms	Grams
gph	Gallons Per Hour
gpm	Gallons Per Minute
HCl	Hydrochloric Acid
HNO_3	Nitric Acid
H_2O, HOH	Water
H_2O_2	Hydrogen Peroxide
H_2	Hydrogen Gas

H^+	Hydrogen Ion
I	Input, Influent
IR	Infrared
JTU	Jackson Turbidity Unit
K	Constant
KH_2PO_4	Potassium Phosphate
LB/DAY	Pounds Per Day
LED	Light Emitting Diode
LIT, L, l	Liter
LTB	Lauryl Tryptose Broth
M	Molar Concentration
m	Constant, Meter
MCL	Maximum Concentration Limit
m^3/s	Cubic Meters Per Second (22.8 MGD)
mc/ml	Millions of Cells per Milliliter
mgal	Millions of Gallons
mgd	Millions of Gallons Per Day
mg/l	Milligrams Per Liter
ml	Milliliters
ml/min	Milliliters Per Minute
MPN	Most Probable Number
mv	Millivolt
N	Normal Concentration
n	Number of Samples
N_2	Nitrogen
NaOH	Sodium Hydroxide

NASA	National Aeronautics and Space Administration
NEDA	N-1 Napthyl-Ethylenediamine Hydrochloride
NH_3	Ammonia
NTU	Nephelometric Turbidity Units
O	Output
O/I	Effluent (Output)/Influent (Input)
O&M	Operations and Maintenance
OZON	Ozonation
PMT	Photomultiplier Tube
POX	Purgeable Organic Halogens
ppb	Parts Per Billion
ppm	Parts Per Million
psi	Pounds Per Square Inch
psig	Pounds per Square Inch Gage
PVC	Polyvinyl Chloride
r	Correlation Coefficient
RDOS	Real-Time Disk Operating System
RO	Reverse Osmosis
RPM	Revolutions Per Minute
RTD	Resistance Thermal Detector
SCVWD-WRF/PA	Santa Clara Valley Water District-Water Reclamation Facility at Palo Alto
sec	Seconds
SiO_2	Silicon Dioxide
sorption	Adsorption or Absorption

TC	Total Carbon
TEC	Techtronics
THC	Total Halocarbons
TOC	Total Organic Carbon
TOX	Total Organic Halogens
UV	Ultraviolet
WMS	Water Monitor System
x	Independent Variable
y	Dependent Variable
μ	Microns, Micro
ug/L	Micrograms per Liter
#	Number
%	Percent
σ	Standard Deviation
σ_E	Standard Error of Estimate
Z	The Number of Standard Deviations from the Mean

SECTION 1

INTRODUCTION

SCVWD-WRF/PA BACKGROUND

The Santa Clara Valley Water District, in cooperation with the Cities of Palo Alto, Los Altos, and Mountain View, embarked upon a developmental program of water reclamation and injection of the reclaimed water into underground aquifers in the South San Francisco bayfront area. The purposes of this program were to demonstrate the technical and economic feasibility of certain reclamation processes, and to attempt to provide a freshwater barrier to the intrusion of saltwater into a shallow aquifer. The wastewater supply to this system is the effluent from the Palo Alto Regional Water Quality Control Plant.

The Water Reclamation Plant provides tertiary treatment to the secondary effluent from the Palo Alto city plant, and in addition to its basic function of providing a supply for groundwater recharge, the reclamation plant can produce water of lesser quality for use in golf course irrigation or as a supplemental supply for the Palo Alto city plant's Reclaimed Water System for in-plant uses.

The project took advantage of unused existing facilities at the Palo Alto plant in the construction of certain process units. An old clarifier was converted to a combined flocculator/clarifier, an unused sludge digestion tank has been used for reclaimed water storage, and an old vacuator structure has been adapted to house filters.

WMS BACKGROUND

As an outgrowth of its involvement in water reclamation and water quality monitoring for both spacecraft and domestic applications, NASA has conducted a project to develop and test an automated WMS (water monitor system). The objective of this project was to develop a system whereby water quality monitoring could be performed as it would be done in a spacecraft, on-line and in real-time. The design goal was to establish the capability to determine conformance to future high effluent quality standards, and thereby increase the potential for reclamation and reuse of wastewater. The resulting system includes both commercially available and NASA-developed sensors, an automated sample collection and distribution system, and a computerized data acquisition and reporting system. The project completed assembly and checkout of the WMS under separate contract (reference 15). The project then entered into the field demonstration test phase which ended on February 28, 1981. The final portion of the test period extended from July 1980 through February 1981. This portion of the test period was jointly funded by NASA, the EPA, the California State Department of Water Resources, and the Santa Clara Valley Water District.

TEST PROGRAM

This report is a summary of test data recorded during the test period, July 1980 through February 1981. Data were recorded on WMS and subsystem downtime and on maintenance and operations costs. Similar data were recorded by the Santa Clara Valley Water District for the reclamation plant. Additional test data were recorded on the quality of the water at various points within the reclamation plant as measured by the sensors within the WMS and the City of Palo Alto Laboratory. These data were used to evaluate the performance, reliability, availability, and costs of the reclamation plant, its individual processes, and the WMS and its components. Major problems encountered in the operation of the WMS and the reclamation plant are discussed.

TEST OBJECTIVES

The objectives of the test program described in this report were as follows:

1. To determine the steady-state performance (ability to remove contaminants) of the water reclamation facility unit processes based on WMS data.

2. To determine unit process and plant availability. Availability is defined as the portion of the time that an item operates on demand. Availability was measured as follows:

   $A = 100T/(T + D)$

   where, A = availability, %
   T = operating time, hours
   D = Downtime for repair, hours
   $T + D$ = total available operating time, hours

   Once established, availability can be used to estimate annual repair time. Thus, for a continuously operated item:

   $D = (1 - A/100)$ (365 days/year) (24 hours/day)

3. To determine plant reliability. Reliability is defined as the percentage of the operating time that an item performs within specified limits. For the water reclamation plant, reliability was measured as the percentage of time that a water quality parameter was within specified effluent limits. The WMS data were statistically evaluated based on a lognormal data distribution model and compared to an MCL (maximum concentration limit). The MCL's for the plant are shown in Table 1. These MCL's are based on references 9, 10, 11, 12, and 13. The percentage of time that a measured parameter was less than the MCL represented plant reliability for that parameter.

TABLE 1
RELIABILITY OF PALO ALTO RECLAMATION FACILITY

	MAXIMUM CONCENTRATION LIMIT MCL	MINIMUM CONCENTRATION LIMIT MCL (MIN)	REFERENCE	RELIABILITY	
				PERIOD A	PERIOD H
CHEMICAL OXYGEN DEMAND	10 mg/l	-	9	65.0% [1]	57.8%
TRIHALOMETHANES	100 mg/l	-	10	>99.9%	>99.9%
TOTAL NITROGEN	5 mg/l	-	9	86.1% (NH_3) [2]	<0.0%
pH	8.5	6.5	9	18.7%	99.9%
DISSOLVED OXYGEN	-	1 MG/L	9	>99.9%	-
HARDNESS	500 mg/l	-	11	78.6%	97.3%
SODIUM	250 mg/l	-	12	>99.9%	-
TOTAL RESIDUAL CHLORINE		1 MG/L	9	76.2%	77.5%
CONDUCTIVITY	1600umho/cm	-	13	>99.9%	70.9%
TURBIDITY	5 NTU		9	-	-

NOTES:

1. ASSUMES COD/TOC RATIO OF 2.5.
2. BASED ON AMMONIA OR NITRATE CONCENTRATION.

The product of multiplying availability times reliability gives the portion of the total available operating time that an item will perform within given limits.

$P = (A)(R)$

where, P = performance achieved
R = reliability, %

4. To determine plant operating and maintenance costs.

5. To determine similar parameters for the WMS; i.e., performance, availability, reliability, and operating and maintenance costs.

SECTION 2

CONCLUSIONS

1. The following conclusions relative to process performance are based on the WMS data:

    a. Chemical clarification removed over 90% of the influent suspended solids (biomass) and as much as 30% of the organic contaminants (TOC).

    b. Flocculation (floc) carryover from the chemical clarification process results in additional loading on the mixed-media filters. This caused decreased filter run times; i.e., more frequent backwashing.

    c. Except for some reduction in trace halocarbons and biomass, the contribution of ozone to water quality does not appear to be significant at the concentrations used in the study.

    d. The removal of ammonia during treatment was not significant. Some biological oxidation to nitrate occurred in the GAC towers.

    e. A reduced level of many dissolved contaminants is characteristic of water processed by activated carbon, when its useful life is not exceeded. However, the COD effluent limit of 10 mg/l is difficult to achieve without significant cost incurred by continuously regenerating carbon.

    f. Just prior to and during the first few weeks of this test period, processing of the influent to the reclamation plant was changed from an activated sludge reactor to a fixed-film reactor with nitrification and dual-media filtration. These changes generally reduced the contaminant levels to the reclamation plant. Data from a 1-month period, which are representative of conditions before these changes, have also been included in this report.

2. The capability to collect and process data for convenient and improved analysis of water quality information has been demonstrated. Over three million water quality measurements were recorded during the test period and are summarized in this report.

3. Both the reclamation plant and the WMS were designed and constructed as experimental test beds where reliability was of secondary importance to flexibility. Neither system was intended to function as an operational system. Rather, they were intended for testing various concepts and

configurations for water treatment, automated quality monitoring and process control. Consequently, the numbers quoted in this report for availability and reliability are not meaningful of the performance that should be expected from operational systems. Rather, the data reported here provide a focus on problem areas which strongly influence reliability. This experience should guide the future design of reliable operational systems.

4. Automated monitoring provides a mechanism for better effluent quality control. Where real-time monitoring is not available, plant- or influent-initiated upsets may go undetected until laboratory test results are received by the operators, which may be several hours or days later. Such a method of operation places a severe restriction on quality control, especially where direct water reuse is involved, and would be unacceptable, for example, in manned spaceflight. Automated, real-time monitoring provides the capability to immediately identify abnormal conditions when they occur, in time to do something about them.

5. Automated water quality monitoring will be an economic necessity in the future as effluent quality control restrictions are tightened. The costs of repetitive laboratory analyses will become prohibitive, thereby increasing the demand for automated sensing, analysis, and reporting.

6. Automated water monitoring offers the potential for reduced water production costs through process and plant configuration control.

7. There is a need for improved reliability of many of the available components used for automated water quality monitoring.

8. The sophistication and advanced technology of some water quality sensors often require highly skilled personnel to isolate and resolve problems. These skills are generally unavailable in many wastewater plants.

9. Interference problems which had previously plagued the NASA-developed coliform sensor have been resolved. However, the complex plumbing arrangement necessary to operate a totally automated multicell sensor is prone to random contamination which, when experienced, has been difficult to eliminate. During the current test period, approximately 1 month of operating time was lost because of contamination. A configuration with less complexity should reduce this problem. Since the potential for reducing the coliform detection time from 72 hours by the laboratory MPN test to 11 hours by the electrode test is quite significant, the system is worthy of further development.

10. Problems have occurred because of different suppliers for WMS computer equipment. In the case of the reclamation plant these problems were avoided by virtue of having single contractor responsibility.

11. The experience of both the reclamation plant and the WMS has been that a computer service contract is key to maximizing system availability.

12. The high labor cost (three-fourths of water production cost) indicates that more attention should be given to maintainability in the design of water treatment and instrumentation systems.

13. Early implementation of a preventive maintenance program for the plant machinery and instrumentation systems can significantly reduce downtime.

14. Process and instrumentation checkout and verification are essential prior to turning the plant over to the operators.

15. The value of plant process instrumentation is significantly reduced if operators are not trained to properly interpret the data.

16. The problems and costs reported here for the water treatment processes may be unique to the equipment and design of this particular facility.

SECTION 3

RECOMMENDATIONS

1. Much of the data collected by the WMS over the 3 1/2 years of operation at SCVWD-WRF/PA, prior to that reported here, have received only cursory review. During that period the plant was operated in several configurations with influent conditions ranging from high quality secondary effluent, which is presented in this report, to low quality influent, including settled primary effluent. The capability now exists and these data should be analyzed, similar to the analysis presented in this report, to show a full range of performance of plant processes.

2. Data exist for periods with and without an operating ozonator. These data should be analyzed to clearly show the net effect of ozonation in a real-world environment and to evaluate cost effectiveness.

3. A test program should be performed to identify key control parameters for effective chemical clarification by lime treatment. The experience at SCVWD-WRF/PA has been that the cost of the process in terms of labor and downtime may offset the benefits in water quality improvement.

4. When using lime for chemical clarification, it is recommended that a filtration step be included prior to GAC sorption. This will reduce the possibility of clogging the GAC with coagulant and/or calcium carbonate precipitant.

5. The potential for reducing activated carbon regeneration costs by operating the towers in a "biologic activated carbon" mode (no regeneration) should be explored.

6. Many operational difficulties after plant startup could be avoided by design verification testing, more intense and continuous operator training, and established requirements for a preventive maintenance program before acceptance from the contractor.

7. The requirements for the installation of computer systems in wastewater plants must consider the environmental requirements of the equipment. Computers must operate in dust and vibration free conditions.

8. Maintain a daily log to be used for recording plant and process downtime, the cause of the downtime, and the number of man-hours required to correct the problem.

9. Maintain a comprehensive record of materials and consumables, including the process in which they are used.

10. The WMS as configured is not ideal. The mobility design criteria dictated its design. The following factors should be considered in designing an in-place integrated plant water quality monitoring system:

    a. Locate electronic equipment in an area away from potential contact with process or other chemical exposure.

    b. Use state-of-the-art computer technology to simplify the data acquisition system. New improved equipment is available almost daily.

    c. Use a single contractor for all computer equipment.

    d. The system should be designed for automatic fault detection. If not, the time required to diagnose electronics failures typically will far exceed the time required to correct the problem.

    e. All sensors should be evaluated with regard to serviceability and cost of consumables prior to purchasing.

    f. Design the sampling system to ensure continuous, adequate sample flow to all sensors.

    g. Take into consideration extensive requirements for drains, vents, air conditioning, and electrical power.

    h. Take into consideration storage requirements for consumables and spares.

    i. Include some laboratory area to do periodic wet chemistry verification work.

11. The NASA-developed biosensor has demonstrated the capability to quantify biological activity at the low concentration levels present in reclamation processes. However, its potential in monitoring and controlling biological treatment processes, such as activated sludge, has not been explored. A vital need for such a capability has been previously identified (reference 14).

12. The NASA-developed coliform sensor should be reconfigured to eliminate complex plumbing thereby improving reliability. The sample size should be increased to provide a minimum sensitivity of one organism per 100 ml. The potential benefits of single analysis units for automated analysis and also for laboratory applications have been previously identified (reference 14).

SECTION 4

WMS (WATER MONITOR SYSTEM)

DESCRIPTION

This section describes the WMS and each of the subsystems. The performance characteristics of each subsystem are evaluated. Operations and maintenance costs are presented for each subsystem. Also included is a discussion of the statistical analysis procedures used in the evaluation of the data obtained by the WMS.

General

The WMS is contained in a 2.4 x 9.0m (8 x 30 ft) transportable semitrailer that includes all the support equipment required to sample various process stages of waste treatment facilities. The WMS configuration is depicted in Figure 1. The instrumentation and computer systems are housed within the trailer, and the sample pumping system, filters, and compressed air supply are secured beneath the trailer. The sample collection and distribution system provides the capability to sample any one of six different sources of water within the treatment process. The WMS has the capability to handle up to 40 data channels. In addition to the GC, the WMS measures 14 water quality parameters. The sensors measuring these parameters are shown in Table 2 with the range, calibration frequency, and the required chemical replacement frequency. With the exception of the last three sensors shown in the table, the sensors are commercially available models that were either available from NASA or bought off the shelf. Where appropriate, these commercial sensors were modified to allow for automatic computer calibration and data acquisition. The remaining three sensors (the coliform detector, the gas chromatograph, and the chemiluminescence biosensor) are based on NASA-developed technology and are unique to the WMS. The elements which comprise the WMS are outlined below. A more complete description of the sensors is presented in reference 4.

Utilities

All utility functions necessary to operate the WMS equipment (except tap water and electrical power) are provided by the WMS trailer. These include air conditioning, compressed air, deionized water, and various reagent gases.

Sample Collection and Distribution System

The sample collection system was designed for multipoint sampling whereby sampling can be accomplished in and about various locations of a wastewater treatment facility. The system has the capability of providing water samples

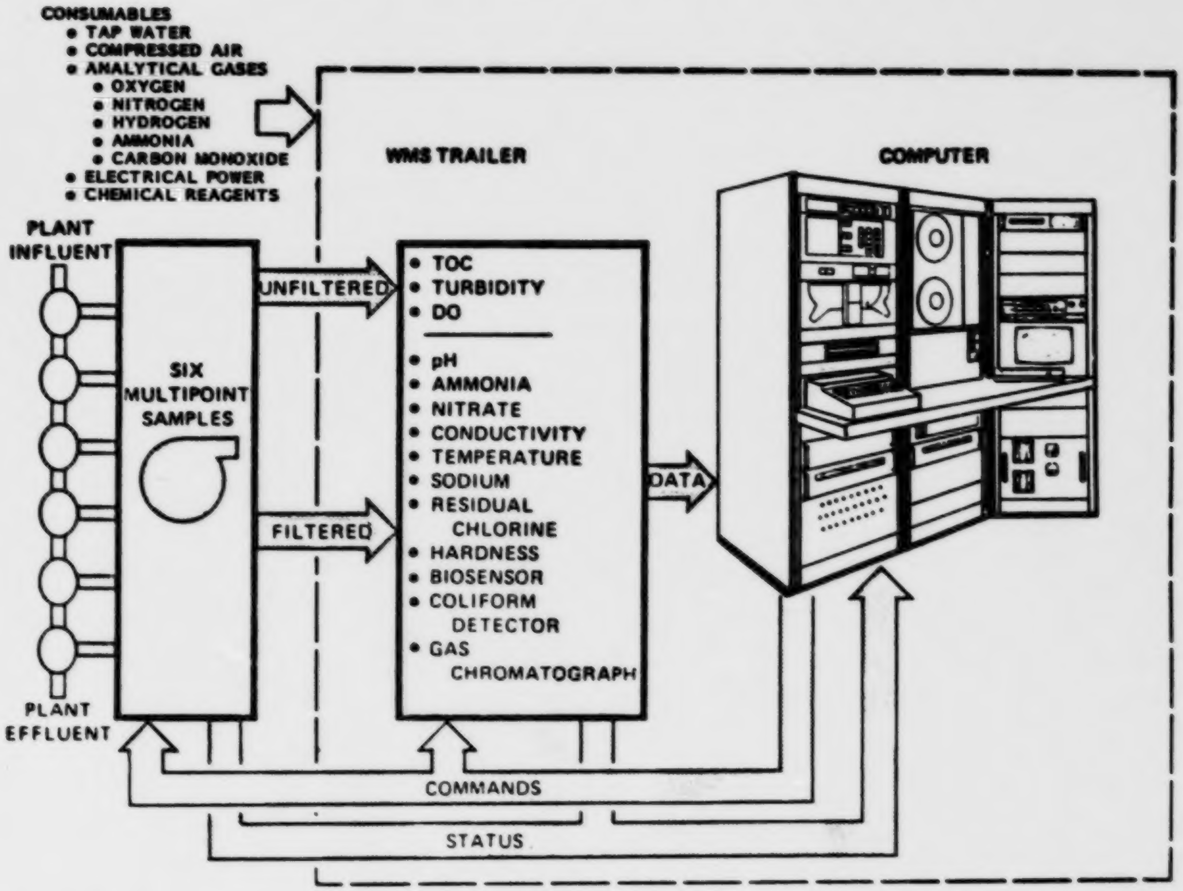

CONSUMABLES
• TAP WATER
• COMPRESSED AIR
• ANALYTICAL GASES
• OXYGEN
• NITROGEN
• HYDROGEN
• AMMONIA
• CARBON MONOXIDE
• ELECTRICAL POWER
• CHEMICAL REAGENTS
WMS TRAILER
COMPUTER
PLANT INFLUENT
PLANT EFFLUENT
SIX MULTIPOINT SAMPLES
UNFILTERED
FILTERED
• TOC
• TURBIDITY
• DO
• pH
• AMMONIA
• NITRATE
• CONDUCTIVITY
• TEMPERATURE
• SODIUM
• RESIDUAL CHLORINE
• HARDNESS
• BIOSENSOR
• COLIFORM DETECTOR
• GAS CHROMATOGRAPH
DATA
COMMANDS
STATUS

Figure 1 Water Monitor System Configuration

TABLE 2
WMS SENSORS

SENSOR	RANGE	STANDARDIZATION FREQUENCY	CHEMICAL REPLACEMENT FREQUENCY
TOC (IR ANALYZER)	0.1 - 1,000 mg/l	DAILY	STD - WEEKLY
HARDNESS (ELECTRODES)	1 - 10,000 mg/l $CaCO_3$	DAILY	STD - WEEKLY REAGENT - 3 MONTHS
RESIDUAL CHLORINE (ELECTRODES)	0.1 - 1,000 mg/l	DAILY	STD - WEEKLY REAGENTS (2) - 3 MONTHS
NITRATE/NITRITE (COLORIMETRIC)	0 - 80 mg/l - N	DAILY	STD - WEEKLY REAGENTS (2) - WEEKLY
AMMONIA (COLORIMETRIC)	0 - 80 mg/l - N	DAILY	STD - WEEKLY REAGENTS (2) - WEEKLY
SODIUM (ELECTRODE)	10 - 1,000 mg/l	DAILY	STD - EVERY 3 DAYS
pH (ELECTRODE)	2 - 12 pH units	WEEKLY	STD - WEEKLY
CONDUCTIVITY (CELL)	0 - 2,000 µmho/cm	WEEKLY	NONE REQUIRED
TEMPERATURE (RTD)	0 - 200°F	WEEKLY	NONE REQUIRED
TURBIDITY (PHOTOMETER)	0.1 - 5,000 mg/l SiO_2	WEEKLY	NONE REQUIRED
DISSOLVED OXYGEN (ELECTRODE)	0 - 20 mg/l	WEEKLY	NONE REQUIRED
COLIFORM DETECTOR	≥ 1 particle /17 ml		EVERY OTHER DAY
GAS CHROMATOGRAPH	≥ 1 µ8/l	EVERY TWO WEEKS	MONTHLY (GASES)
CHEMILUMINESCENCE BIOSENSOR (TOTAL & VIABLE)	≥ 10^5 particles/ml	EVERY TWO WEEKS	EVERY 3 DAYS

from six different locations at predetermined intervals. Figure 2 presents the configuration and flow schematic of the system.

Total and Viable Biomass

A chemiluminescence biosensor has been developed for monitoring bacterial population in wastewater streams. The system employs the alkaline luminol-hydrogen peroxide reaction with iron porphyrins as a total bacteria monitor. Hydrogen peroxide pretreatment, reaction rate differentiation, and EDTA allow the resolution and quantitation of bacteria in the presence of the interfering materials associated with wastewater effluents. Incorporation of a carbon monoxide technique permits the measurement of both total and viable bacteria in an automated flowing system.

To measure viable bacteria with an automated luminol chemiluminescence system, the laboratory single sample injection method developed at Goddard Space Flight Center was converted to a flowing system where reagents and samples are transported with peristaltic pumps. The major problem was the handling of the carbon monoxide-treated sample. It was known that light reverses the binding of the carbon monoxide with iron porphyrins of viable bacteria. The carbon monoxide pretreatment had to be performed in the dark and the sample had to be protected from light until after the subsequent analysis. This was achieved by locating the carbon monoxide bubble chamber in a dark box and by using black tubing for transferring the sample from the chamber to the reaction coil.

In addition to the carbon monoxide required for the determination of viable bacteria, air had to be bubbled through the sample for accurate determination of total bacteria. Without the air treatment, total bacteria counts were artifically high, a fact still unexplained.

The biosensor schedule originally required 2 hours for a measurement of both total and viable bacteria. The schedule was later shortened to 1 hour after tests confirmed that sample flush, air/carbon monoxide treatments, and analysis could be accomplished with sufficient quantitative accuracy.

A standard calibration method was developed to insure the accuracy and repeatability of the sensor. Calibrations were established using the Coulter electronic particle counter and the firefly luciferase - ATP assay for total and viable bacteria, respectively. These are illustrated in Figure 3 and Figure 4. They were reproducible for samples of cultured coliform bacteria or effluent samples. The correlation coefficient was 0.96. The viable bacteria correlation curve illustrated in Figure 4 shows much more scatter when cultured bacteria and effluent samples are compared. This may be due not so much to variations in biosensor response but to variations in the ATP levels within the organisms grown in different environments and subject to various degrees of stress.

The standard curve generated from the measurement of total bacteria is used for the calibration of the sensor. The stability and repeatability of these measurements make it the method of choice. Extensive research in the

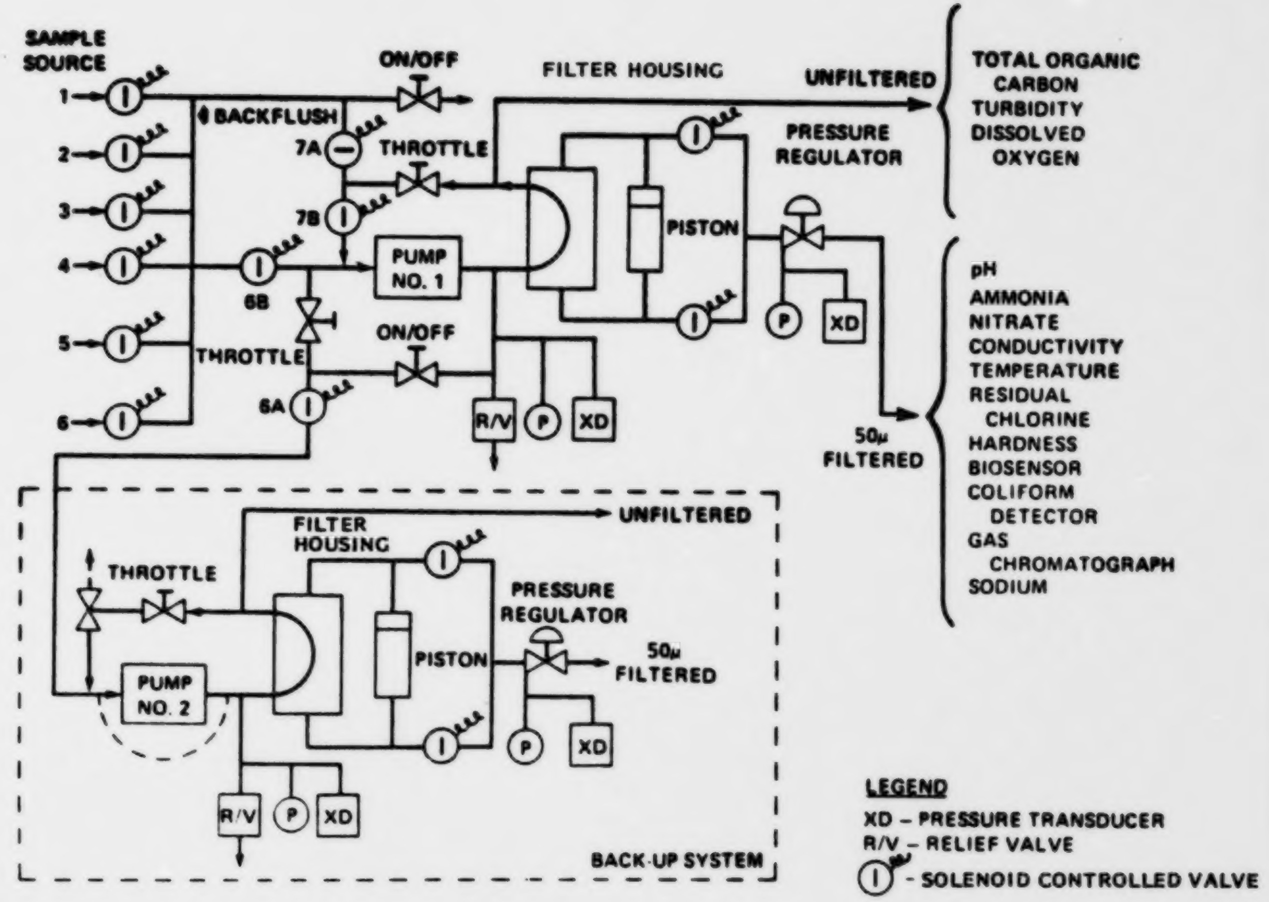

SAMPLE SOURCE
1
2
3
4
5
6
ON/OFF
BACKFLUSH
7A
7B
THROTTLE
6B
PUMP NO. 1
THROTTLE
ON/OFF
6A
R/V
P
XD
FILTER HOUSING
PISTON
UNFILTERED
PRESSURE REGULATOR
P
XD
50μ FILTERED
TOTAL ORGANIC CARBON
TURBIDITY
DISSOLVED OXYGEN
pH
AMMONIA
NITRATE
CONDUCTIVITY
TEMPERATURE
RESIDUAL CHLORINE
HARDNESS
BIOSENSOR
COLIFORM DETECTOR
GAS CHROMATOGRAPH
SODIUM
THROTTLE
PUMP NO. 2
FILTER HOUSING
UNFILTERED
PISTON
PRESSURE REGULATOR
50μ FILTERED
R/V
P
XD
P
XD
BACK-UP SYSTEM
LEGEND
XD – PRESSURE TRANSDUCER
R/V – RELIEF VALVE
– SOLENOID CONTROLLED VALVE

Figure 2 Sample Collection and Distribution Flow Schematic

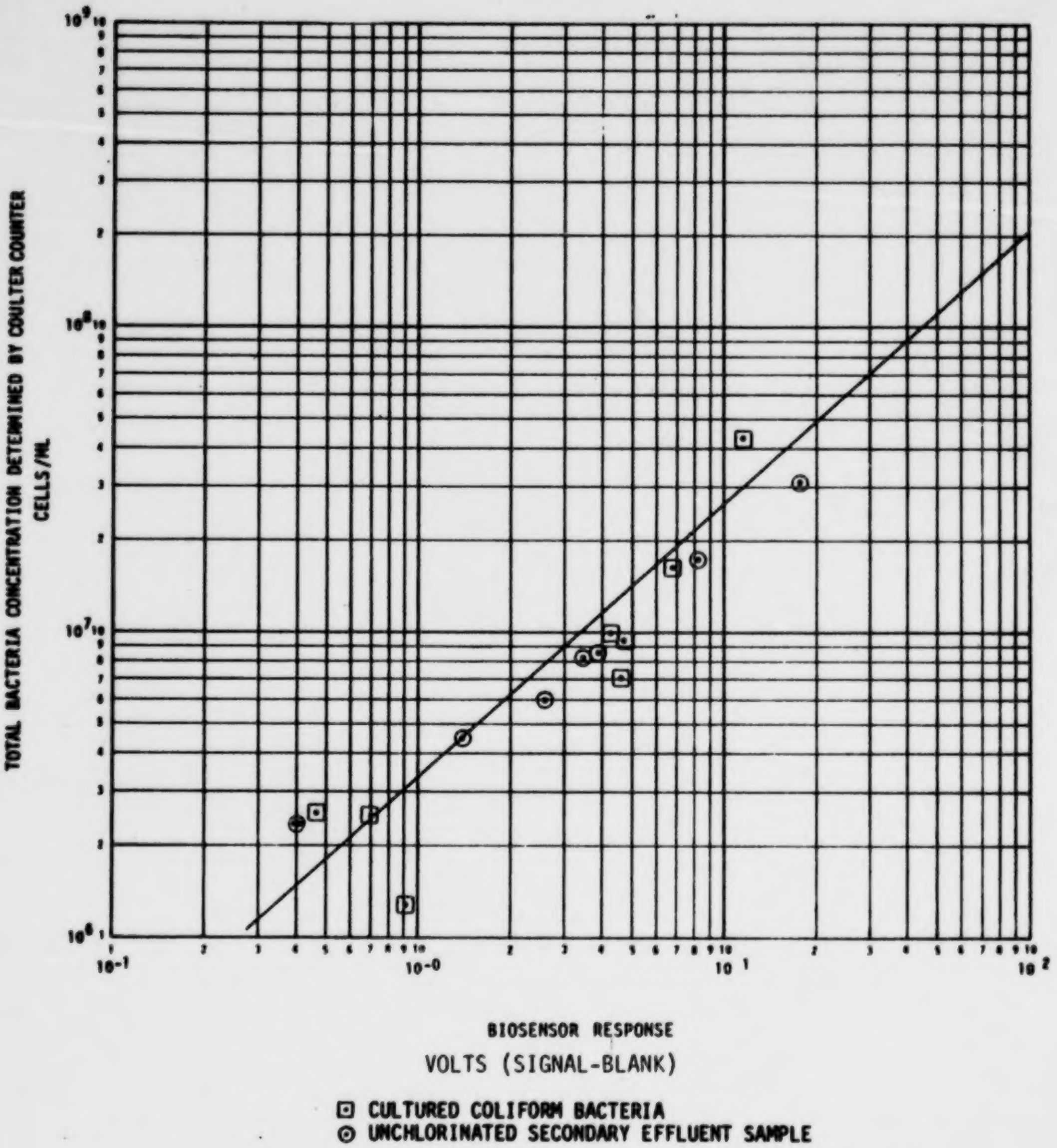


Figure 3 **Biosensor Calibration Curve Established for Total Bacteria**

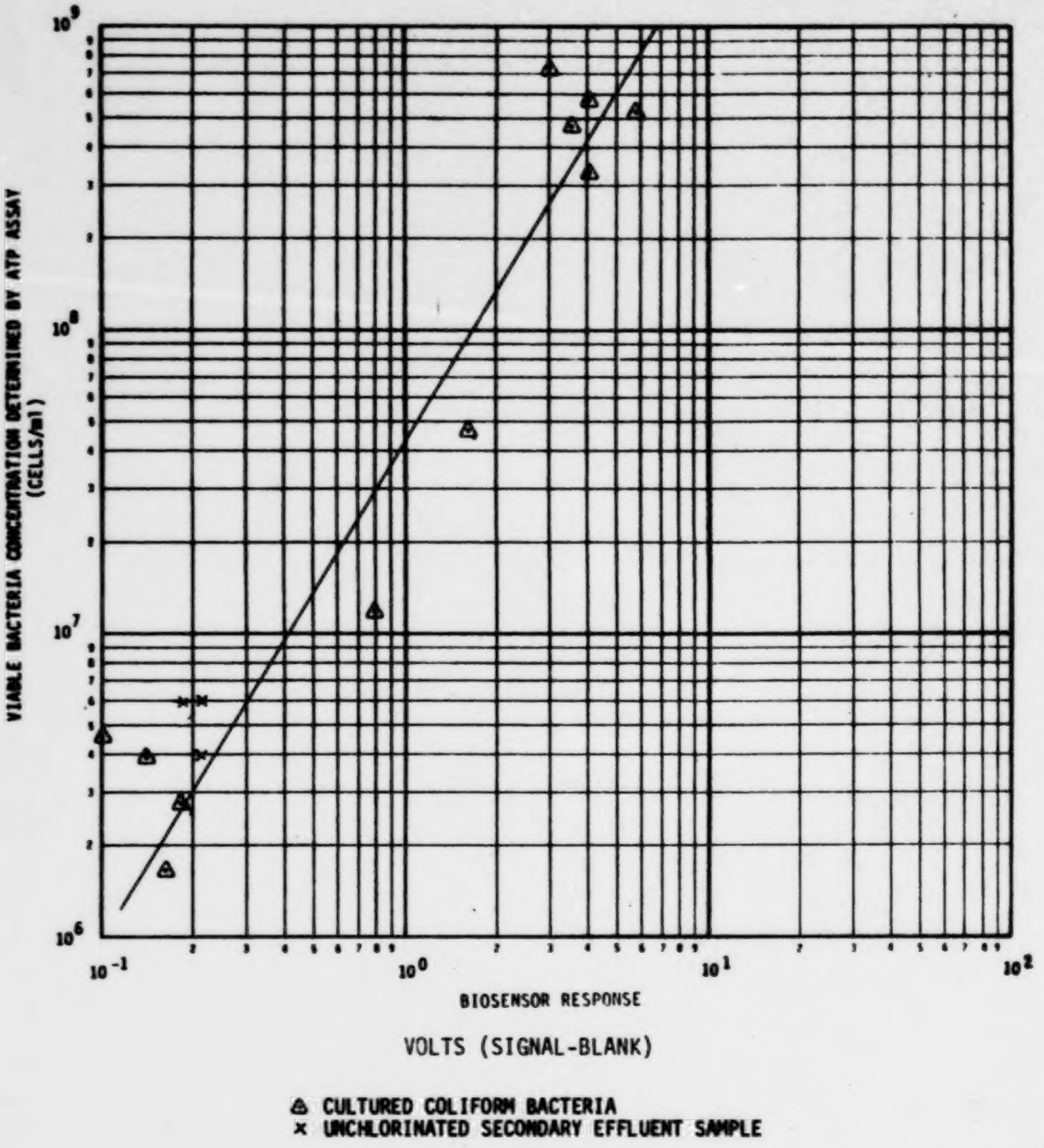


Figure 4 Biosensor Response versus Viable Bacteria as Determined by the Firefly Luciferase - ATP Assay

laboratory supports the extension of the method to calculate viable bacteria with relative confidence.

Figure 5 is a schematic of the chemiluminescence biosensor including positions of Buchler peristaltic pumps, valves, and other associated apparatus. A sample is pumped at 4.35 ml/min. and mixed with 0.02% H_2O_2 flowing at 0.35 ml/min. The sample is in contact with the final 0.0015% solution of H_2O_2 for 2 minutes. This H_2O_2 pretreatment step is designed to eliminate interferences from extracellular iron porphyrins by oxidative degradation while not significantly affecting intracellular porphyrins protected by the cellular membrane. Ninety-five percent removal of these interferences is effected using this pretreatment.

The H_2O_2 pretreated sample is pumped into the bubble chamber at 4.7 ml/min. An assay of the air-treated sample produces a measurement of total bacteria, live as well as dead organisms, due to the stability of the iron porphyrins within an intact cellular membrane. An analysis of a carbon monoxide-bubbled sample is a measure of dead bacteria only.

An actively respiring bacterium absorbs carbon monoxide that irreversibly binds with the iron porphyrin members of the electron transport chain. Luminol chemiluminescently reacts with the oxidized iron porphyrins of the dead bacteria; however, no reaction occurs with the reduced carbon monoxide-complexed iron porphyrins found in the metabolizing organisms. The difference in chemiluminescent response between an air-treated sample (live and dead bacteria) and carbon monoxide-treated bacteria (dead bacteria only) can be directly related to the concentration of metabolizing bacteria.

The air/CO-treated sample, pumped at 0.20 ml/min., is then mixed with the luminol reagent (5.64×10^{-3} M luminol, 1.5 N sodium hydroxide, 40.6×10^{-3} M EDTA, and 0.1% H_2O_2) at 0.20 ml/min. A 10-second residence time is incorporated in the line before the photomultiplier tube to eliminate the short-lived chemiluminescence signals from interfering agents such as chlorine and transition metals.

The chemiluminescent signal is measured using an Aminco Chem-Glow Photometer equipped with a coiled glass flow cell. The computer records the output of the photometer and converts the values to bacteria counts in units of millions of cells/ml based on blank and calibration factors.

Table 3 contains the schedule for computer actuation of valves and commands to calculate the results. The first 5 minutes of the schedule, step 1, allows the sample lines to flush without flowing sample to the bubble chamber. This step is designed to prevent cross-contamination of the previous hour's sample with the current sample source. Step 2 fills the bubble chamber with sample while bubbling air through the sample for a total of 10 minutes. The chemiluminescence response is measured and recorded during step 3 which lasts 19 minutes. Step 4 signals the computer to average the last five recorded values and calculate the total bacteria concentrations based on the calibration factors. Steps 5, 6, and 7 are similar to steps 2, 3, and 4, except carbon

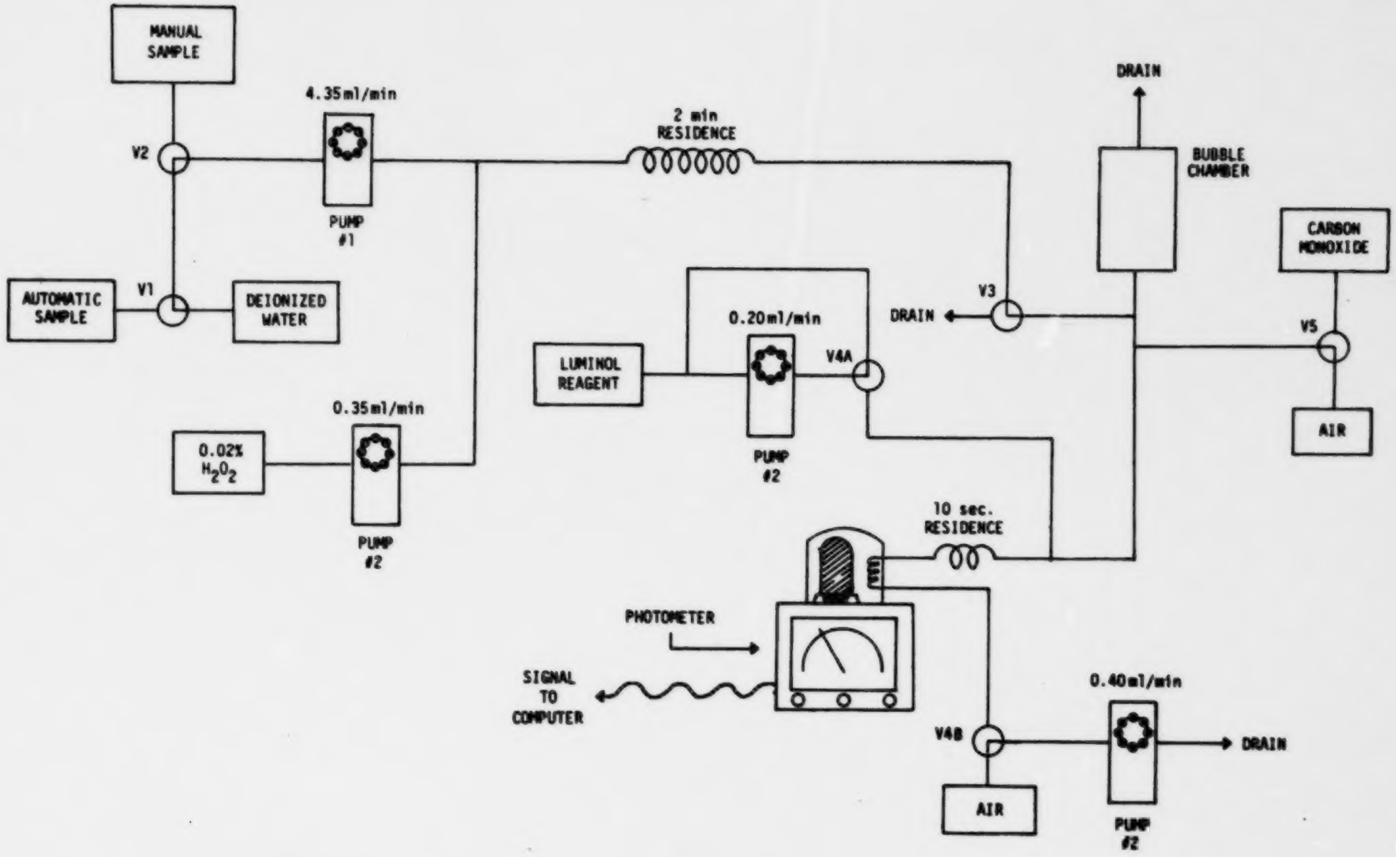

MANUAL SAMPLE
V2
4.35ml/min
PUMP #1
2 min RESIDENCE
DRAIN
BUBBLE CHAMBER
CARBON MONOXIDE
V5
AIR
AUTOMATIC SAMPLE
V1
DEIONIZED WATER
LUMINOL REAGENT
0.20ml/min
PUMP #2
V4A
DRAIN
V3
0.02% H2O2
0.35ml/min
PUMP #2
10 sec. RESIDENCE
PHOTOMETER
SIGNAL TO COMPUTER
V4B
AIR
0.40ml/min
PUMP #2
DRAIN

Figure 5 Chemiluminescence Biosensor Schematic for Monitoring Total and Viable Bacteria

monoxide is bubbled for use in the calculation of viable bacteria. The computer retains the value for total bacteria calculated in step 4, then subtracts the value of dead organisms calculated in step 7. The difference is recorded as the viable bacteria.

TABLE 3. BIOSENSOR HOURLY SCHEDULE

STEP	VALVE ENERGIZED TIME HR:MIN:SEC	CUMULATIVE TIME HR:MIN:SEC	ENERGIZED VALVES
1.	0: 5: 0	0: 5: 0	1, 3
2.	0:10: 0	0:15: 0	1
3.	0:19: 0	0:34: 0	1, 3, 4
4.	0: 1: 0	0:35: 0	1, 3, 4
5.	0: 5: 0	0:40: 0	1, 3, 5
6.	0:19: 0	0:59: 0	1, 3, 4, 5
7.	0: 1: 0	1: 0: 0	1, 3, 4, 5

Total Residual Chlorine

An Orion Model 1125 Chlorine Analyzer measures the residual chlorine in continuous samples by the potentiometric method. It operates on the principle that chlorine will liberate free iodine from potassium iodide solutions when the pH is 8 or lower. The sample is mixed with a reagent and pumped through a reaction heater and constant temperature analysis chamber. In the chamber, the mixture passes between a sodium electrode and redox electrode. The electrodes are connected to the analyzer's electronics system which gives a direct chlorine concentration reading on a four-cycle logarithmic scale calibrated to read from 0.1 to 1000 mg/l.

Turbidity

A Sigrist Photometer Turbidimeter Model UP 52-TJ determines the turbidity of a continuous sample stream by comparison with a nephelometric standard. The Model UP 52-TJ has four measuring attachments of different ranges. Two of the units use falling-stream flow cells with ranges of 2-1000 and 2000-15,000 mg/l (SiO_2); one uses a surface scatter-flow cell with a range of 5-100 mg/l; and one uses a splash-flow cell with a range of 0.5-20 mg/l. All of them use a dual beam optical measuring bridge. The flow attachment used during the current test period was the Model TJ25 which measures light scatter at 25 degrees in a falling stream. The manufacturer claims that this configuration gives the best sensitivity for detecting low concentrations of biological solids.

Dissolved Oxygen

A Delta Scientific Series 8310 Automatic Analyzer continuously measures dissolved oxygen in a sample stream. The patented DO probe consists of gold and silver electrodes mounted in a PVC body. A Teflon membrane forms an oxygen-permeable barrier between the water being tested and the electrolyte in the probe. A voltage is applied across the electrode and as oxygen passes through the membrane, it produces an electrical current proportional to its concentration. DO readings in mg/l in the ranges of 0-2, 0-10, or 0-20 are displayed.

TOC (Total Organic Carbon)

The TOC measurements presented in this report were obtained using one of two TOC analyzers. The TOC analyzer originally installed in the WMS was an Astro Ecology Model 1100 TOC/TC Analyzer using a high temperature reactor to obtain conversion of organic carbon to carbon dioxide. The replacement low temperature TOC analyzer, Astro Ecology Model 1800, was installed in April 1980. A more complete description of the two analyzers follows.

The Astro Ecology Corporation high temperature TOC analyzer simultaneously determines either TC (total carbon) or TOC on aqueous samples containing solid particulates up to 2000 micrometers in diameter. Measurement ranges from 0-10 mg/l or 0-500 mg/l of carbon are available. Fifty ml/min. of sample are continuously pumped into a mixing chamber and gas scrubber assembly where it is mixed with phosphoric acid to reduce the pH to 2. Inorganic carbon is converted to carbon dioxide which is vented to an air stream. A portion of the scrubbed, carbonate-free sample (2 ml/min.) is pumped into a combustion chamber and combined with a metered air stream (79% oxygen). The air provides the oxygen for combustion. The sample remains in the chamber at 850°C long enough for full combustion to occur. The products of combustion and excess air leave the reactor and enter a water-cooled liquid/gas separation assembly which removes condensed vapors. The remaining gases are routed to an infrared analyzer where the amount of carbon dioxide is measured and converted to units of TOC.

The Astro Ecology Corporation low temperature TOC analyzer is capable of measuring either TC or TOC. The analyzer is continuously operated in the TOC mode for WMS applications. The following theory of operation refers to Figure 6. The incoming sample is pumped into the analyzer at the nominal rate of 28 ml/min. by P1(M1), a peristaltic pump. Approximately 4 ml/min. of this flow is transferred via P3(M2) to the inorganic carbon scrubber assembly (S-1), and the balance is bypassed to drain. A phosphoric acid solution, pumped by P5(M3) at .21 ml/min. from acid reservoir (R-2), is added to this stream before it reaches the CO_2 scrubber. This acid addition converts 98% of the inorganic carbon to CO_2 which is then scrubbed out of the solution. Scrubber oxygen flow is introduced at the bottom of (S-1) and is controlled by FIC-2 at 150 ml/min. All excess sample entering (S-1) is bypassed by overflow to drain. Pump P4(M2) draws 0.3 ml/min. from (S-1)'s overflow. This sample is mixed first with a carrier gas (zero grade oxygen) and then with a persulfate solution, delivered by P6(M3) at .21 ml/min., and delivered to the reactor module UV-1. In the reactor module all carbon in the sample is converted to CO_2. The oxidized

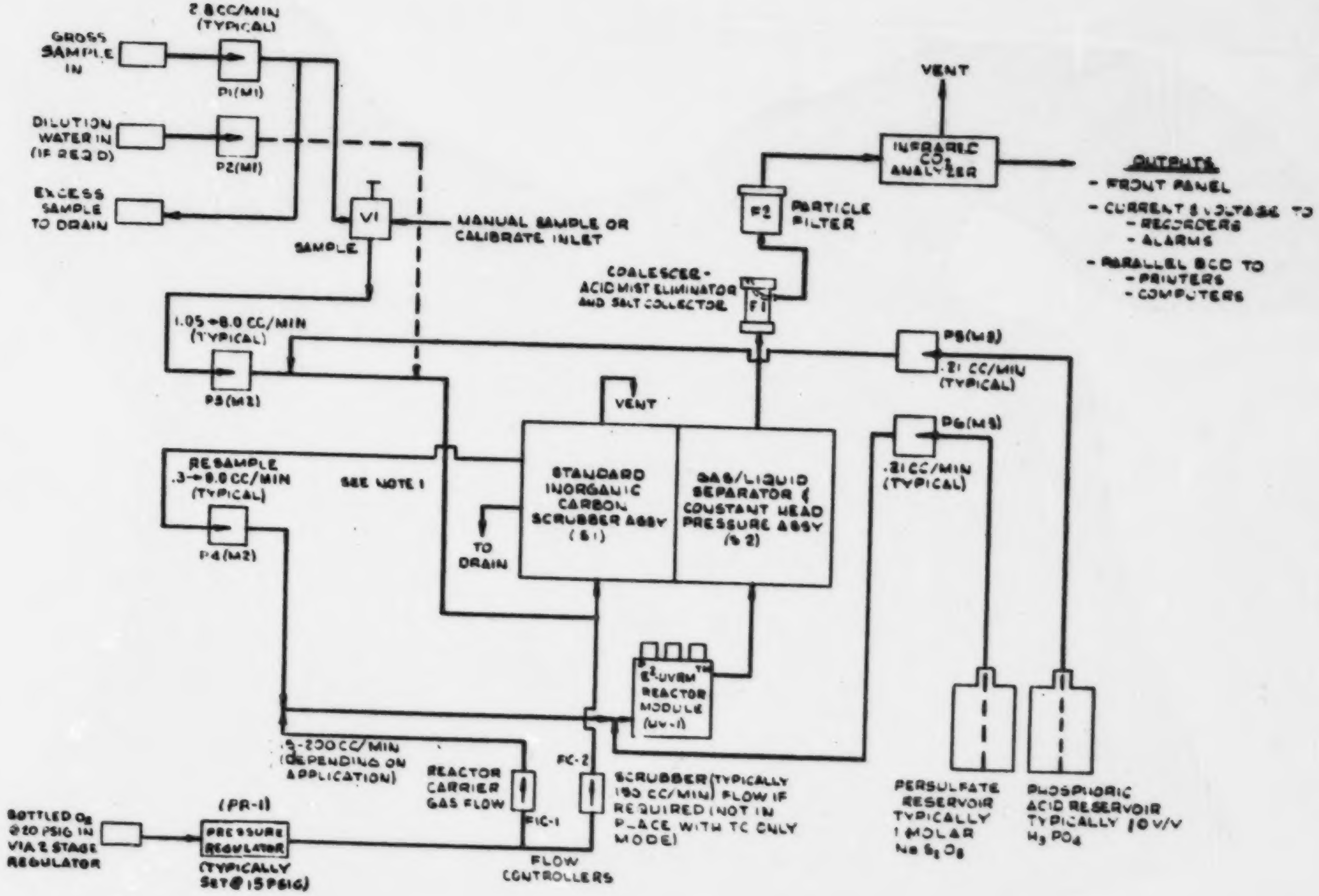

2.8 CC/MIN (TYPICAL)
GROSS SAMPLE IN
P1(M1)
DILUTION WATER IN (IF REQ'D)
P2(M1)
EXCESS SAMPLE TO DRAIN
V1
SAMPLE
MANUAL SAMPLE OR CALIBRATE INLET
1.05→8.0 CC/MIN (TYPICAL)
P3(M2)
RESAMPLE .3→8.0 CC/MIN (TYPICAL)
P4(M2)
SEE NOTE 1
VENT
STANDARD INORGANIC CARBON SCRUBBER ASSY (S1)
GAS/LIQUID SEPARATOR & CONSTANT HEAD PRESSURE ASSY (S2)
TO DRAIN
COALESCER-ACID MIST ELIMINATOR AND SALT COLLECTOR
F1
F2
PARTICLE FILTER
VENT
INFRARED CO2 ANALYZER
OUTPUTS
- FRONT PANEL
- CURRENT & VOLTAGE TO
- RECORDERS
- ALARMS
- PARALLEL BCD TO
- PRINTERS
- COMPUTERS
P5(M3)
.21 CC/MIN (TYPICAL)
P6(M3)
.21 CC/MIN (TYPICAL)
E²UVRM™ REACTOR MODULE (UV-1)
.5-200 CC/MIN (DEPENDING ON APPLICATION)
REACTOR CARRIER GAS FLOW
FC-1
FC-2
SCRUBBER (TYPICALLY 150 CC/MIN) FLOW IF REQUIRED (NOT IN PLACE WITH TC ONLY MODE)
FLOW CONTROLLERS
BOTTLED O2 @20 PSIG IN VIA 2 STAGE REGULATOR
(PR-1)
PRESSURE REGULATOR
(TYPICALLY SET@15PSIG)
PERSULFATE RESERVOIR TYPICALLY 1 MOLAR Na S2 O8
PHOSPHORIC ACID RESERVOIR TYPICALLY 10 V/V H3 PO4

Figure 6 Total Organic Carbon Sensor Flow Schematic

sample solution then passes through (S-2) (gas-liquid separator and constant head overflow assembly) and the liquid portion is directed to drain. The vapor portion of the sample, now laden with CO_2 and other by-products, leaves from the top of (S-2). This vapor passes through (F-2) (filter element) before delivery to the infrared analyzer for CO_2 analysis.

Ammonia

A Delta Scientific Model 8119 Ammonia Analyzer continuously measures ammonia in sample water by spectrophotometric analysis. The intensity of the blue color developed by the reaction of ammonia with phenol and hypochlorite in an alkalin medium is proportional to the concentration of ammonia in the sample. The analyzer has a minimum sensitivity of 0-1 mg/l ammonia, and no upper limit with dilution.

Nitrate/Nitrite

A Delta Scientific Model 8138-153105-002XX1 Nitrate Analyzer continuously measures nitrate/nitrite concentrations in the sample stream by spectrophotometric analysis. Nitrates are reduced to nitrites in a cadmium-reducing column. The nitrites are then reacted with sulfanilamide and NEDA in an acid solution to form the azo dye. The color intensity developed is a measure of the nitrate plus nitrite concentration in the sample. The concentration of nitrites may be determined separately by bypassing of the cadmium column. Nitrate/nitrite concentrations above 0.4 mg/l are too dark for useful discrimination; therefore, dilution of the sample is required for most measurements.

pH

The GLI (Great Lakes Instruments) Model 70 Analyzer measures pH using the differential electrode technique to compare a pH electrode to a standard electrode containing a chemical pH standard. The probe is housed in a 1 1/2-inch PVC tee to increase the flow velocity across the probe.

Conductivity

The sensor used to measure the ionic content of the water sample is a Beckman Type R15 Solu Bridge Conductivity Indicator with a temperature-compensated epoxy flow-through cell, type CEL-VDJ4-KF. The cell constant is 4.0, permitting measurements in the range of 0-2000 mhos/cm.

Temperature

The Action Pac RTD's (Resistance Thermal Detectors) are used to measure sample temperatures. The RTD probe detects changes in potential between two electrodes as the temperature changes and converts this to a 0 to 5-volt signal. The probe is sensitive to 0.1°F and reads from 0-200°F.

Hardness

An Orion Model 1132 Hardness Analyzer continuously monitors the sample stream for hardness, a measure of calcium and magnesium ions in water. The technique used is proprietary to Orion Instrument Company. In general the method involves the chelation of all divalent ions by a complexing agent, followed by the addition of a "substitution" ion which selectively releases calcium ions. A "tag" ion is added at molar concentrations 100 times greater than the maximum possible ionic strength. A reference electrode is selective to this tag ion, and the sensing electrode is selective to the substitution ion. The electrodes are connected to the analyzer's electronics system which gives a direct hardness reading on a four-cycle logarithmic scale calibrated to read from 0.1 to 1000 mg/l.

Sodium

The Beckman Model 9415 Sodium Ion Analyzer determines the concentration of sodium in a sample stream by measuring the potential between a Beckman 633951 Sodium Ion Electrode and a Beckman 19604 reference electrode. The electrode potential is directly proportional to the logarithm of the active sodium concentration. The response of the sodium electrode can be affected by several other monovalent cations. Usually, hydrogen is the only interfering ion with sufficient concentration to be a problem. To eliminate this interference, all solutions are pH adjusted with ammonia to suppress the hydrogen ion concentration. Temperature control is provided by a heat exchanger located upstream of the electrode flow chamber.

Gas Chromatograph

The gas chromatograph quantitatively measures nine volatile halogenated hydrocarbons. The system, linked to the 30- filtered multipoint sample source, automatically injects 120 1 of sample into a preparative gas chromatograph which separates the organic compounds from the water. The organics are collected on a Tenax GC trap which is heated to introduce the compounds into the analytical gas chromatograph for accurate quantitation at the microgram per liter level. The following compounds are routinely monitored during the 50-minute analysis:

1) Tetrachloroethylene
2) Methylene Chloride
3) 1,2-Dichloroethylene
4) Chloroform
5) 1,1,1-Trichloroethane
6) Bromodichloromethane
7) Trichloroethylene
8) Dibromochloromethane
9) Bromoform

These include; trichloroethanes, choloroform, bromodichloromethane, dibromochloromethane, and bromoform.

The system is interfaced with the Nova 3 for data transfer, storage, and retrieval.

The automated gas chromatograph consists of two basic subsystems. The first subsystem, which includes a sampling valve, preparative gas chromatograph

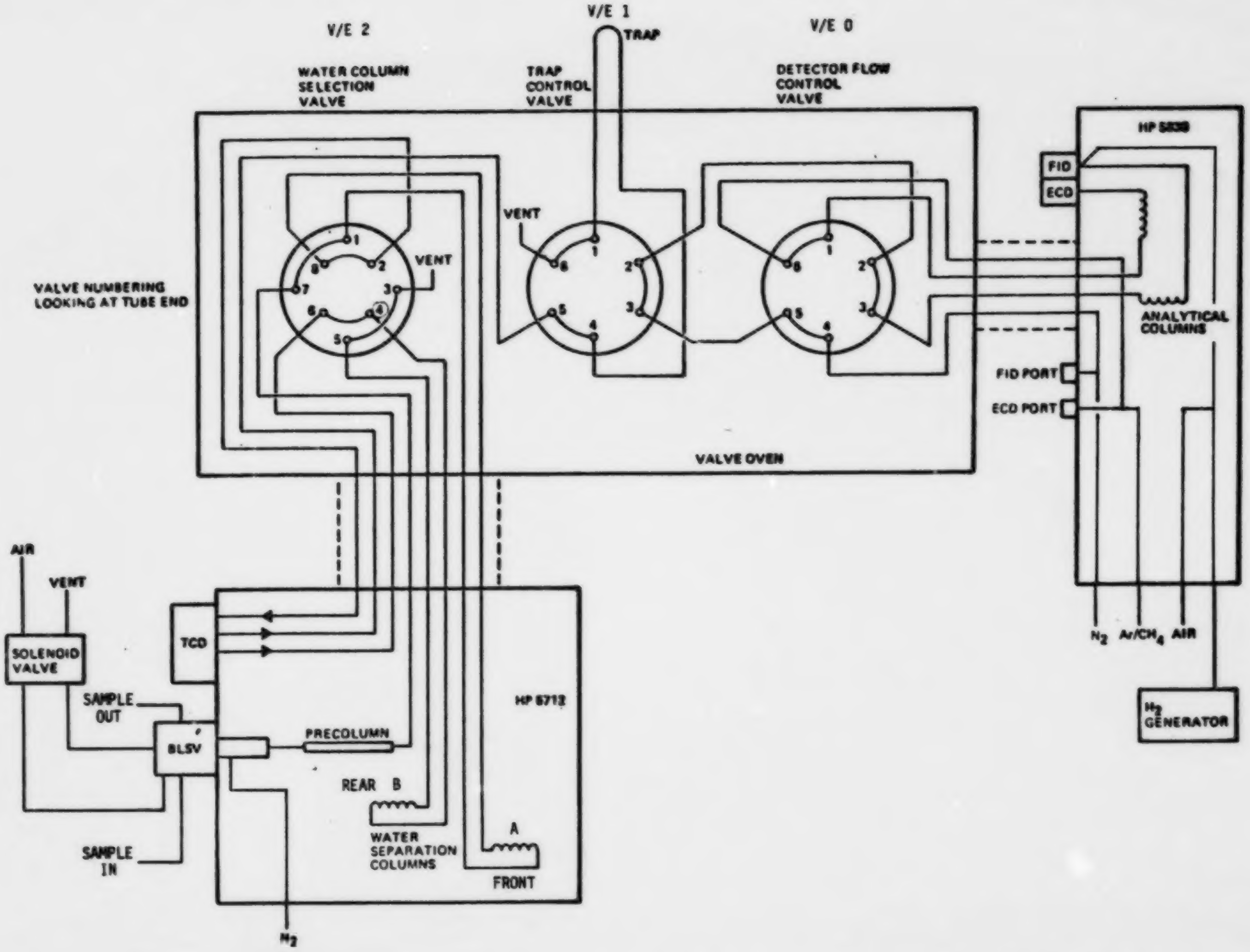

V/E 2
WATER COLUMN SELECTION VALVE
V/E 1
TRAP
TRAP CONTROL VALVE
V/E 0
DETECTOR FLOW CONTROL VALVE
VALVE NUMBERING LOOKING AT TUBE END
1
2
3
4
5
6
7
8
VENT
VENT
VALVE OVEN
HP 5830
FID
ECD
ANALYTICAL COLUMNS
FID PORT
ECD PORT
N2
Ar/CH4
AIR
H2 GENERATOR
AIR
VENT
SOLENOID VALVE
SAMPLE OUT
SAMPLE IN
BLSV
TCD
HP 5712
PRECOLUMN
REAR B
WATER SEPARATION COLUMNS
A
FRONT
N2

Figure 7 Automated Gas Chromatograph Water Analysis System Flow Schematic

and trap, is required to separate and concentrate the volatile chlorinated organics from the water sample. The concentrated sample is then routed to the analytical gas chromatograph which performs the quantitative analysis. Figure 7 is a schematic of the complete system.

The preparative gas chromatograph is a Hewlett-Packard Model 5710 equipped with a thermal conductivity detector. This chromatograph is fitted with a short Sorbital precolumn and a pair of 0.635 cm o.d. x 137 cm stainless steel columns packed with 10% Sorbitol and 0.5% Igepal 50-880 on 50/80 mesh Gas Chrom Q. The column oven is operated isothermally at 105°C. A 99.999% nitrogen carrier gas flow is maintained at 15 ml/min. The sample is introduced into the preparative gas chromatograph via a Bendix liquid sampling valve mounted on top of the unit. The sampling valve injection port is maintained at 150°C.

The preparative gas chromatograph is fitted with an external valve oven maintained at 150°C. This valve oven houses two automatically controlled Carle Model 2014 microvolume sampling valves and lines connecting the preparative and analytical gas chromatograph subsystems. Valve 2 permits selection of the water column in the preparative gas chromatograph. Valve 1 allows sample flow to pass through the trap or to the atmosphere. A trap consisting of 10.2 cm x 15.2 cm stainless steel tubing packed with 60/80 mesh Tenax GC extends outside the external oven to allow rapid heating and cooling. Heating is accomplished by a commerical blower/heater, and cooling is attained by blowing ambient air across the trap.

The analytical gas chromatograph consists of a Hewlett-Packard Model 5840 equipped with an electron capture detector. The detector oven is maintained at 225°C and the injection port temperature at 175°C. The analytical column consists of a 355 cm x 0.312 cm o.d. stainless steel column packed with 0.2% Supelco SP-1000 on 80/100 Carbopak C. The carrier gas flow is maintained at 14 ml/min. For an analysis, the column is maintained at 80°C for 28 minutes, then programmed to rise to 175°C at 8°/minute. A mixture of 95% argon and 5% methane is used as the carrier gas in the analytical gas chromatograph.

The gas chromatograph system is interfaced to the computer system for calculations and storage of data. The area values calculated by the gas chromatograph are transferred to the computer through the communications interface. The computer calculates the absolute concentrations for the nine compounds based on established calibration curves. The concentrations of the compounds are then stored on the disk system for later retrieval.

Before a water sample is processed, the Tenax trap is heated for 1 minute and purged with nitrogen. The analytical column is heated to 200°C for 5 minutes to remove any residual volatile materials. Valve 2 is rotated before each analysis, thus alternating the two identical water separation columns. This allows one preparative column to be used while the other preparative column is being purged. When the trap is cooled to about 25°C and the analytical column cooled to 80°C, the water sample analysis can proceed.

Sample (120 1) is injected into the preparative column by six pneumatic actuations (20 1 per injection) of the liquid sampling valve. The sample is immediately volatilized as it passes through the 175°C heated port. The sample then passes through valve 2 and into the water separation column. As the sample passes through this column, the organics separate from the water fraction and are eluted first onto the trap. By monitoring the column effluent with the thermal conductivity detector, the organics are collected on the trap until just prior to the emergence of the water fraction. At this point, valve 1 is actuated to vent the water vapor to the atmosphere and put the trap in line with the analytical column.

The concentrated organics are desorbed by heating the trap to 285°C for 15 seconds. The organics are then carried into the column in the analytical gas chromatograph by the argon/methane carrier gas. The output from the electron capture detector of this gas chromatograph is transmitted to the WMS computer system where concentrations are calculated and stored.

The entire volatile organic analysis is completed in 50 minutes. The first 10 minutes is used to heat and purge both the trap and analytical column of any residual organic compounds. The next 10 minutes is required for the separation and collection of the organic fraction of the water sample. The last 30 minutes is required for the analysis of the volatile organic compounds and transmission of the data to the computer. The entire procedure is repeated each hour, 24 hours a day.

Total and Fecal Coliform

The coliform sensor is designed to automatically analyze water samples daily for coliform concentrations. Coliform bacteria characteristically evolve hydrogen gas during the metabolism of the disaccharide lactose. In solution, molecular H_2 (hydrogen) and H+ (hydrogen ion) establish an equilibrium in the presence of noble metals such as platinum according to the following equation:

$$H_2 \overset{Pt}{\rightleftharpoons} 2H^+ + 2e^-$$

The potential of this reaction may be measured using a commerical combination electrode such as Calomel-Platinum. It had been observed that the time from inoculation to detection of hydrogen is inversely proportional to the initial inoculation cell count for coliform organisms. The coliform detector quantifies organisms of this group on the basis of the hydrogen produced. Figure 8 is a flow schematic of the coliform detector.

The coliform sensor is packaged in a standard 19-inch cabinet. The sensor includes four subsystems: Manual and automatic control switch panel, four incubator and four buffer cells, fluids storage and transfer equipment, and instrumentation. Manual and automatic control of the sensor is accomplished through a switch control panel. Automatic control of cleanup, buffer purging, nutrient fill, and inoculation procedures are provided by the computer. Manual control is available for performing maintenance procedures. The four incubator cells are serially connected by 1.6mm four-way Teflon valves to a common fluid fill-and-drain manifold. In addition, each nutrient cell is connected to a similar cell filled with 1.0% KH_2PO_4 buffer. The purpose of the buffer cells is the collection and measurement of hydrogen gas. The cells are 25mm by 15mm borosilicate glass tubes. The top of each cell is fitted with a silicone

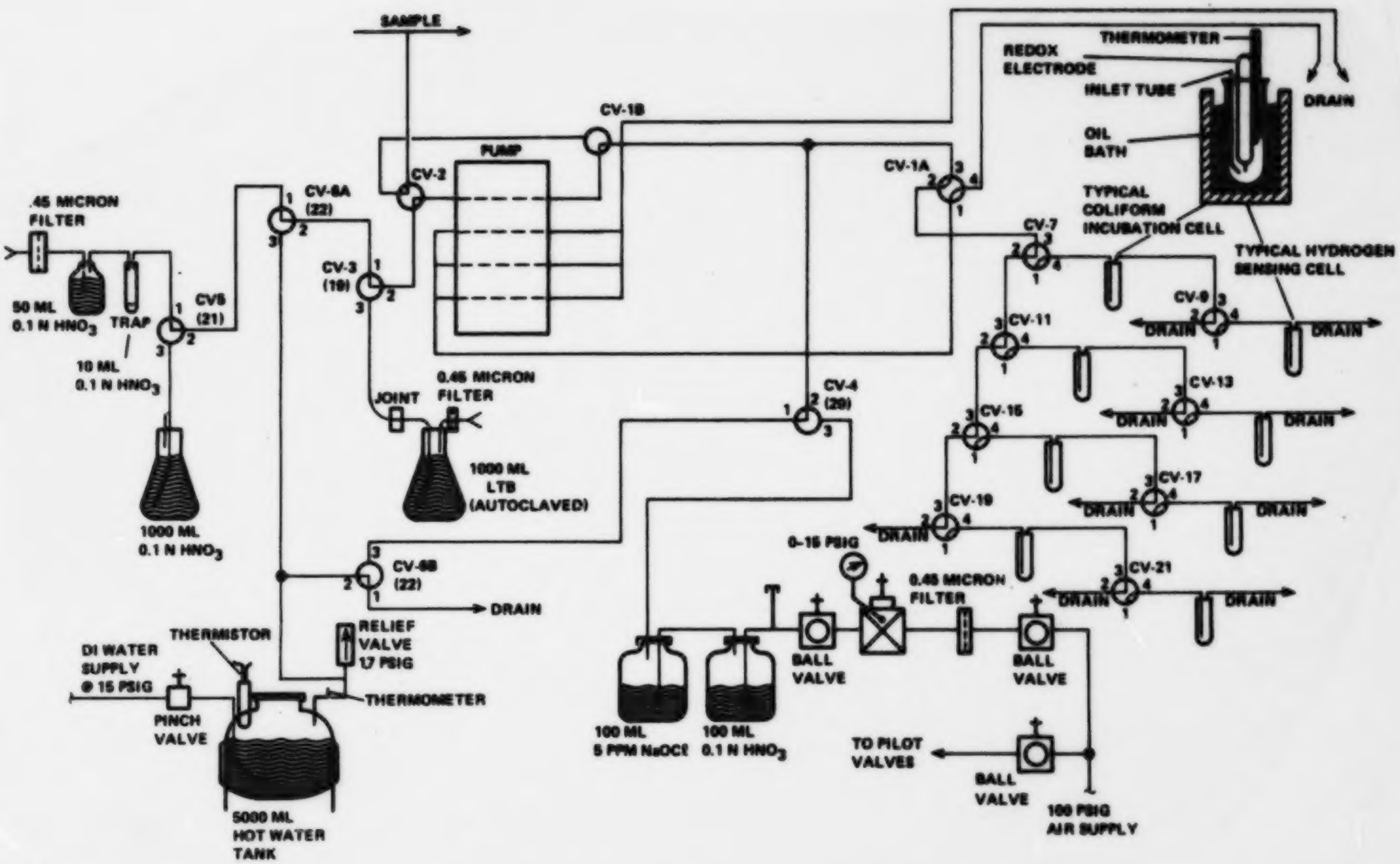

SAMPLE
.45 MICRON FILTER
50 ML 0.1 N HNO$_3$
TRAP
10 ML 0.1 N HNO$_3$
CVS (21)
1000 ML 0.1 N HNO$_3$
CV-6A (22)
CV-2
CV-3 (19)
PUMP
CV-1B
JOINT
0.45 MICRON FILTER
1000 ML LTB (AUTOCLAVED)
CV-6B (22)
DRAIN
DI WATER SUPPLY @ 15 PSIG
THERMISTOR
PINCH VALVE
5000 ML HOT WATER TANK
RELIEF VALVE 17 PSIG
THERMOMETER
CV-4 (20)
100 ML 5 PPM NaOCl
100 ML 0.1 N HNO$_3$
BALL VALVE
0-15 PSIG
0.45 MICRON FILTER
BALL VALVE
TO PILOT VALVES
BALL VALVE
100 PSIG AIR SUPPLY
CV-1A
THERMOMETER
REDOX ELECTRODE
INLET TUBE
OIL BATH
DRAIN
TYPICAL COLIFORM INCUBATION CELL
TYPICAL HYDROGEN SENSING CELL
CV-7
CV-9
CV-11
CV-13
CV-15
CV-17
CV-19
CV-21
DRAIN

Figure 8 Coliform Sensor Flow Schematic

stopper molded for two 1.6mm fill-and-vent tubes, a 12mm combination electrode, and a mercury thermometer. Teflon is used wherever possible to enhance cleaning. Each of the cell tubes is immersed in a mineral oil bath which can be individually controlled at temperatures of 35°C (total coliform) or 44.5°C (fecal coliform) and a bacteriostat temperature of 85°C. The bath is heated with electrical resistance heaters, and temperatures are maintained with solid state proportional controllers. The buffer cells are operated at room temperature.

The fluids storage and handling section includes valves, peristaltic pump, reagent storage containers, regulated facility air, and hot demineralized water. Air supplies are filtered to 0.45 micron and washed in 0.1 N nitric acid. Water is heated to 100°C with 30 minutes retention time to effect sterilization. Organism growth is monitored with one combination electrode per cell. The electrode signal is conditioned with high impedance amplification and multiplexed to the computer for visual display and engineering unit printout. Temperatures may be monitored visually with a mercury thermometer.

The coliform sensors' cleanup and inoculation processes are controlled by a 57-step computer program. The cleanup and inoculation processes are shown in Table 4. The first 45 steps involve evacuating the previous sample, cleaning and sterilizing the reaction cells, purging the hydrogen gas from the buffer cells, and introducing fresh broth into the incubator cells. Step number 46 is a 48-hour holding step which was devised to allow the operator a variable waiting period between inoculations. The remaining steps inoculate the sample with the final step being a holding step during which hydrogen production by organism growth is monitored by the EVE minicomputer.

An extensive amount of work was done prior to the test period to develop a series of calibration curves. The information gathered was used to compare this sensor to another which used an impedance measuring technique, establish sensitivity and reproducibility limits, and to demonstrate the degree of agreement between the sensor values and the MPN values from the laboratory.

In order to calibrate the sensor, seeded samples were run and the reaction times were plotted against the lab MPN values obtained on the sample. The samples consisted of serial dilutions of unchlorinated secondary effluent using chlorinated secondary effluent (which had been dechlorinated) as diluent. The dechlorinated water was used as diluent in order to approximate the chemical composition of real-world samples. Figures 9 and 10 show the fecal and total calibration curves which were obtained in the manner mentioned above. Linear regression analyses were run and gave the slope, y intercept, and r values for each calibration. For the fecal coliform calibration, the values were -1.26, 10.45 hrs., and 0.95, respectively. For the total coliform the calibration curve values were -0.9, 9.04 hrs., and 0.95, respectively. By using the equation $y = mx+b$, the unknown (the original number of coliform bacteria in the sample) may be calculated. Whereas y equals the original coliform concentration, m equals the slope, and b equals the y intercept. The reaction time is designated as the amount of time required to register a 200 mv drop from the electrode output.

In the course of operating the coliform sensor, several cultures of bacteria (coliform and noncoliform) were obtained. It was discovered that several

TABLE 4

COLIFORM SENSOR SCHEDULE

STEP	VALVE ENERGIZED TIME	CUMULATIVE TIME	ENERGIZED VALVES	2/20/81
1.	0: 8: 0	0: 8: 0	17.21.23.	DRAIN CELLS 17 = DRAIN 21 = HNO_3 FLOW 23-35 = INLET VALVES FOR CELLS 1,3,5,7
	0: 5: 0	0:13: 0	17.21.31.	
3.	0: 5: 0	0:18: 0	17.21.27.	
4.	0: 5: 0	0:23: 0	17.21.35.	
5.	0:15: 0	0:38: 0	21.23.	ADD HNO_3 TO CELLS 21 = HNO_3 23-35 = INLET VALVES FOR CELLS 1,3,5,7
6.	0:15: 0	0:53: 0	21.31.	
7.	0:15: 0	1: 8: 0	21.27.	
8.	0:15: 0	1:23: 0	21.35.	
9.	0: 4: 0	1:27: 0	20.	FLUSH MAIN LINE WITH AIR 20 = COMPRESSED FILTERED AIR
10.	0: 1: 0	1:28: 0	20.35.	FLOW COMPRESSED AIR THRU HNO_3 IN CELLS TO AGITATE 20 = COMPRESSED AIR 23-35 = INLET VALVES FOR CELLS
11.	0: 1: 0	1:29: 0	20.27.	
12.	0: 1: 0	1:30: 0	20.31.	
13.	0: 1: 0	1:31: 0	20.23.	
14.	0: 5: 0	1:36: 0	17.21.35.	DRAIN HNO_3 FROM CELLS AND BEGIN 95° HEAT SOAK 17 = DRAIN 21 = HNO_3 FLOW 23-35 = INLET VALVES 53-41 = 95° (INCUBATORS)
15.	0: 5: 0	1:41: 0	17.21.27.	
16.	0: 5: 0	1:46: 0	17.21.31.	
17.	0: 5: 0	1:51: 0	17.21.23.53.	
18.	0:15: 0	2: 6: 0	22.23.49.53.	FLUSH WITH HOT D.I. HOH AND A SOAK 22 = HOT D.I. HOH 35-23 = CELL VALVES 53-41 = 95° (INCUBATORS)
19.	0:15: 0	2:21: 0	22.31.45.49.53.	
20.	0:15: 0	2:36: 0	22.27.41.45.49.53.	
21.	0:15: 0	2:51: 0	22.35.41.45.49.53.	
22.	0: 8: 0	2:59: 0	17.21.23.41.45.	DRAIN HOH FROM CELLS START SECOND SOAK 17 = DRAIN 21 = HNO_3 FLOW 23-35 = INLET VALVES
23.	0: 8: 0	3: 7: 0	17.21.31.41.45.	
24.	0: 8: 0	3:15: 0	17.21.27.41.	
25.	0: 8: 0	3:23: 0	17.21.35.41.	
26.	0: 5: 0	3:28: 0	20.	CLEAR MAIN LINE WITH AIR 20 = AIR
27.	0: 5: 0	3:33: 0	20.23.25.	PURGE BUFFER CELLS WITH COMPRESSED AIR 20 = AIR 23-35 NUTRIENT CELL INLET 25-37 BUFFER CELL INLET
28.	0: 5: 0	3:38: 0	20.27.29.	
29.	0: 5: 0	3:43: 0	20.31.33.39.	
30.	0: 5: 0	3:48: 0	20.35.37.	
31.	0:10: 0	3:58: 0	19.41.45.49.53.	FLUSH MAIN LINE WITH NUTRIENT 19 = NUTRIENT FLOW
32.	0: 4: 0	4: 2: 0	19.23.41.45.49.53.	NUTRIENT FILL AND SOAK 19 = NUTRIENT 23-35 = INLET VALVES 41-45 95° FOR 4 NUTRIENT CELLS
33.	0: 4: 0	4: 6: 0	19.31.41.45.43.53.	
34.	0: 4: 0	4:10: 0	19.27.41.45.49.53.	
35.	0: 4: 0	4:14: 0	19.35.41.45.49.53.	

TABLE 4

COLIFORM SENSOR SCHEDULE

(Continued)

STEP	VALVE ENERGIZED TIME	CUMULATIVE TIME	ENERGIZED VALVES	2/20/81
36.	0: 5: 0	4:19: 0	20.41.45.49.53.	FLUSH MAIN LINE WITH AIR 20 = COMPRESSED AIR
37.	0: 1: 0	4:20: 0	23.41.45.49.53.	OPEN NUTRIENT CELL INLET VALVES TO ALLOW PUMP TO DRAIN CELL LINES INTO CELL COMPLETE SOAK
38.	0: 1: 0	4:21: 0	31.41.45.49.53.	
39.	0: 1: 0	4:22: 0	27.41.45.49.53.	
40.	0: 1: 0	4:23: 0	35.41.45.49.53.	
41.	0:16: 0	4:39: 0	22.41.45.49.53.	FLUSH MAIN LINE WITH HOT DI HOH AND COMPLETE SOAK 22 = HOT DI HOH
42.	0: 8: 0	4:47: 0	21.41.45.49.53.	FILL MAIN LINE WITH HNO_3 21 = HNO_3
43.	0: 6: 0	4:53: 0	17.21.41.45.49.53.	FLUSH SAMPLE CUP LINE WITH HNO_3
44.	0: 8: 0	5: 1: 0	22.	FLUSH MAIN LINE WITH HOT DI
45.	0: 6: 0	5: 7: 0	17.22.	FLUSH SAMPLE CUP LINE WITH DI
46.	48: 0: 0	53: 7: 0	22.	HOLDING STEP FLUSH MAIN LINE WITH HOT D.I.
47.	0:10: 0	53:17: 0	18.	FLUSH MAIN LINE WITH SAMPLE 18 = SAMPLE VALVE
48.	0: 4: 0	53:21: 0	18.23.	FILL CELLS WITH (14ml) OF SAMPLE 18 = SAMPLE VALVE 23-35 CELL VALVES
49.	0: 4: 0	53:25: 0	18.27.	
50.	0: 4: 0	53:29: 0	18.31.	
51.	0: 4: 0	53:33: 0	18.35.	
52.	0: 6: 0	53:39: 0	20.	CLEAR MAIN LINE WITH COMPRESSED AIR
53.	0: 1: 0	53:40: 0	23.	OPEN INLET VALVES TO ALLOW PUMP TO DRAIN CELL LINES INTO CELL COMPLETE SOAK
54.	0: 1: 0	53:41: 0	27.	
55.	0: 1: 0	53:42: 0	31.	
56.	0: 1: 0	53:43: 0	35.	
57.	0: 1: 0	53:44: 0	22.25.29.33.37.39.	FLUSH MAIN LINE WITH HOT D.I. OPEN BUFFER CELL INLET VALVES VALVES REMAIN ENERGIZED UNTIL NEXT CLEANUP 22 = D.I. 25-37 = INLET VALVES 39 = DUMMY VALVES

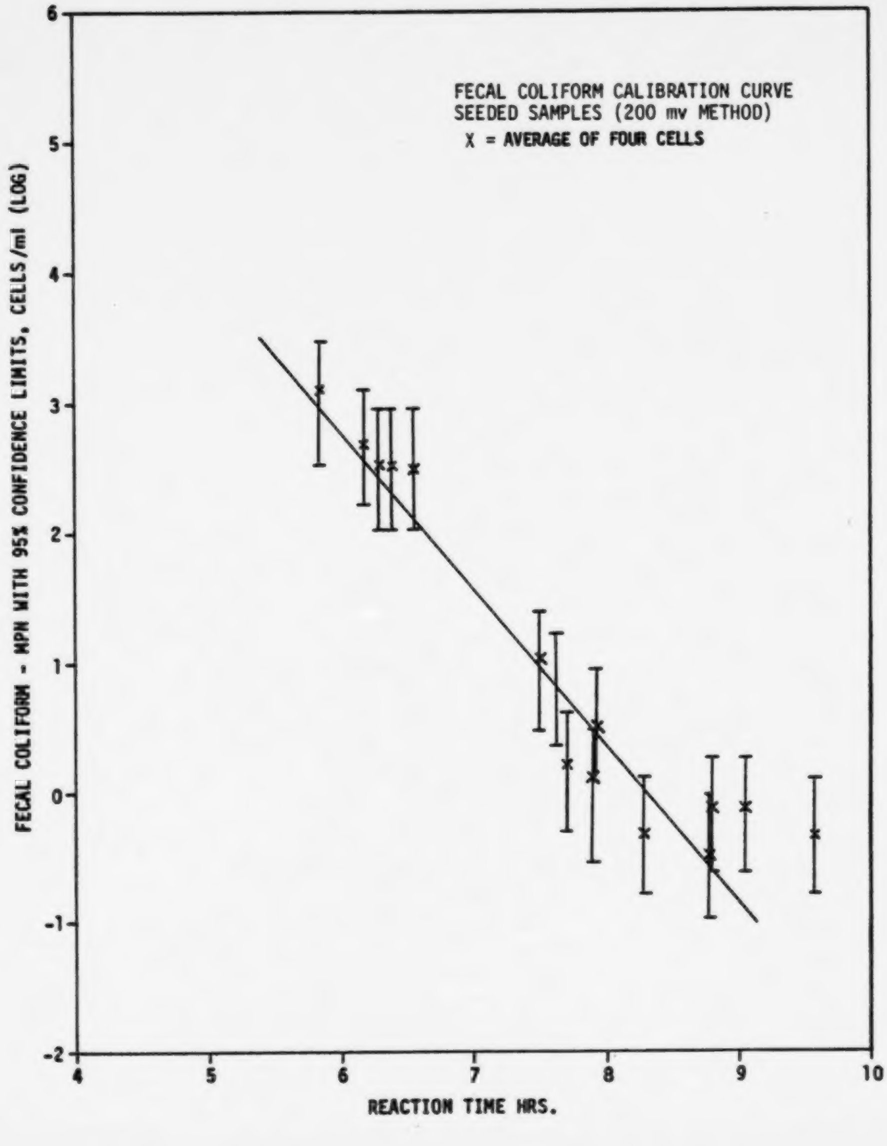


Figure 9 Coliform Sensor Calibration-Fecal Coliform

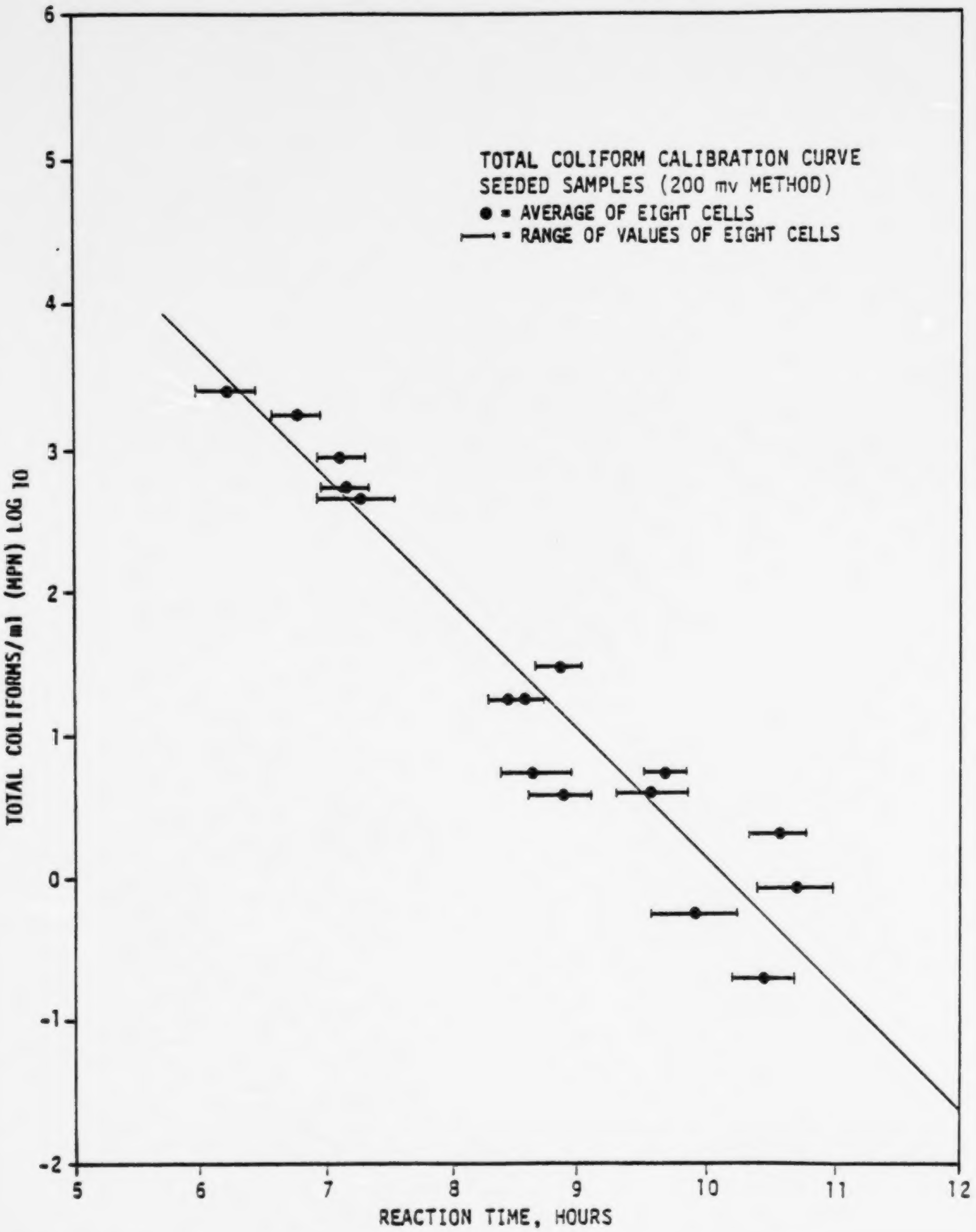


Figure 10 Coliform Sensor Calibration-Total Coliform

strains of noncoliform bacteria mimicked the electrode response of coliform bacteria. This was a revelation in that previous experience had shown that noncoliform bacteria were incapable of driving the electrodes to the maximum negative point (-500 mv). These particular cultures, however, gave electrode responses equal to those of coliforms.

After it became apparent that the electrode response was influenced by end products of metabolism other than hydrogen, a new cell configuration was devised allowing four of the eight test cells to see only gases evolved in the four test cells containing broth. This provides four pairs of test cells with each pair consisting of a broth cell and a buffer cell. This is the configuration currently being used.

Data Acquisition and Report Generation System

The WMS was developed as a method for providing automatic operation and control of the instrumentation and sample collection system necessary to determine the physical/chemical and biological activity of water discharged from waste treatment facilities. Two computer systems, ADAM (Air Data Acquisition and Monitoring) and EVE (Environmental Verification and Evaluation), accomplish this objective by separate data acquisition and report generation tasks. ADAM is a commerical software package developed to control air quality monitoring stations which acquire and check data, perform engineering unit conversions and automatic instrumentation standardization and calibration, and data reporting. EVE is a companion program developed to reformat the ADAM data for retention and display, to operate and control biological sensors and a gas chromatograph, and to plot or analyze the results.

The separate computer systems for data acquisition and report generation were developed to utilize the proven data processing capabilities of the ADAM system and provide flexibility to generate various reports and allow future expansion. The proprietary aspects of the ADAM software do not allow program modifications to be made to the data acquisition system; therefore, any required changes are performed on the EVE report generation system which is coded in FORTRAN and resides on the disk system.

The combined system of computers provides a wide range of capabilities for immediate determination and evaluation of water quality. Instantaneous and historical reports are available for display on either a CRT for immediate review or a line printer for hard copies or plotted results. The ADAM system was purchased from Monitor Labs, Inc., San Diego, CA, and the EVE system was developed by Boeing Aerospace Company to provide additional reporting and control capability not available in ADAM. ADAM is a stand-alone operating system that functions independently from EVE and operates and controls the sample collection system and the commerical sensors that measure the physical and chemical activity of the water samples. EVE utilizes the Data General Corporation RDOS (Real-Time Disk Operating System) to acquire the ADAM data, process and control the biological sensors, acquire the gas chromatograph data, and store and report the results.

The commercial sensors are hardwired to the ADAM system. These include total organic carbon, turbidity, dissolved oxygen, pH, ammonia, nitrate/nitrite, conductivity, temperature, sodium, residual chlorine, hardness, sample pumping pressures and reclamation plant chemical clarification operational parameters (influent flow pH, recycle flow, waste flow and sludge density). There are 40 data channels available for continuous real-time monitoring.

The computer system is secured in three adjoining equipment racks as shown in Figure 11. The ADAM system is racked within the left equipment bay and the EVE system is racked within the center and right equipment bays. The ADAM computer system, Figure 12, consists of a Data General NOVA 1200 computer with 24K words of memory, a Monitor Labs Data Logger, Time-of-Year Clock, and a peripheral device control interface; a Remex paper tape reader/punch; and an NCR thermal printer and keyboard. The EVE system computer equipment, Figure 13, consists of a Data General NOVA 3D computer with 64K words of mapped memory, a disk system with one fixed and one removable cartridge with 10 megabytes storage capacity, a magnetic tape, and a communication chassis with a four-line asynchronous multiplexer; a Monitor Labs peripheral device control interface and an A/D converter; two TEC CRT data screens and keyboards; and a Versatec matrix printer/plotter. Separate cables are provided for the Remex paper tape reader/punch and Data General magnetic tape to allow access by either computer system. Except for the magnetic tape and the communication chassis on the EVE system, all peripheral communication is accomplished through each Monitor Labs device control interface. The Data General communication chassis is used on the EVE system to receive the ADAM commercial sensor data and the gas chromatograph data via two EIA RS232C data lines that are multiplexed for access by the operating system. A second CRT is used on the EVE system for background communication with the operating system.

The Digital Clock provides the main system time base to sample the digital data from the Data Logger. A selectable time pulse is transmitted through the Interface to the NOVA 1200 cpu. The NOVA 1200 cpu responds by calling the remote station via a Serial Input/Output device in the interface unit. The remote station then reads the analog input signals and proceeds to transmit the digital data. The NOVA 1200 cpu checks the incoming data for errors, stores the information, and performs calculations for transmission to the communication chassis.

Operator control of the WMS is provided by a separate communication device for each computer system. The ADAM system communication is provided by a thermal printer and keyboard. The EVE system communication is provided by two CRT data screens and keyboards. Hard copies of the EVE reports and plotted results are printed on a line printer. A data scan is performed each minute by the ADAM system, the data are transmitted to the EVE system, and the results are displayed on one of the CRT data screens. Instrument status, current or instantaneous data, and previous or historical data from EVE are monitored. Required channel calibration data and standardization valve actuation data for ADAM are entered on the keyboard.

The WMS provides the capability to automatically monitor 40 parameters each minute and generates reports for instantaneous data or for historical data of the current day or any previous day within a 3 month period. Instantaneous

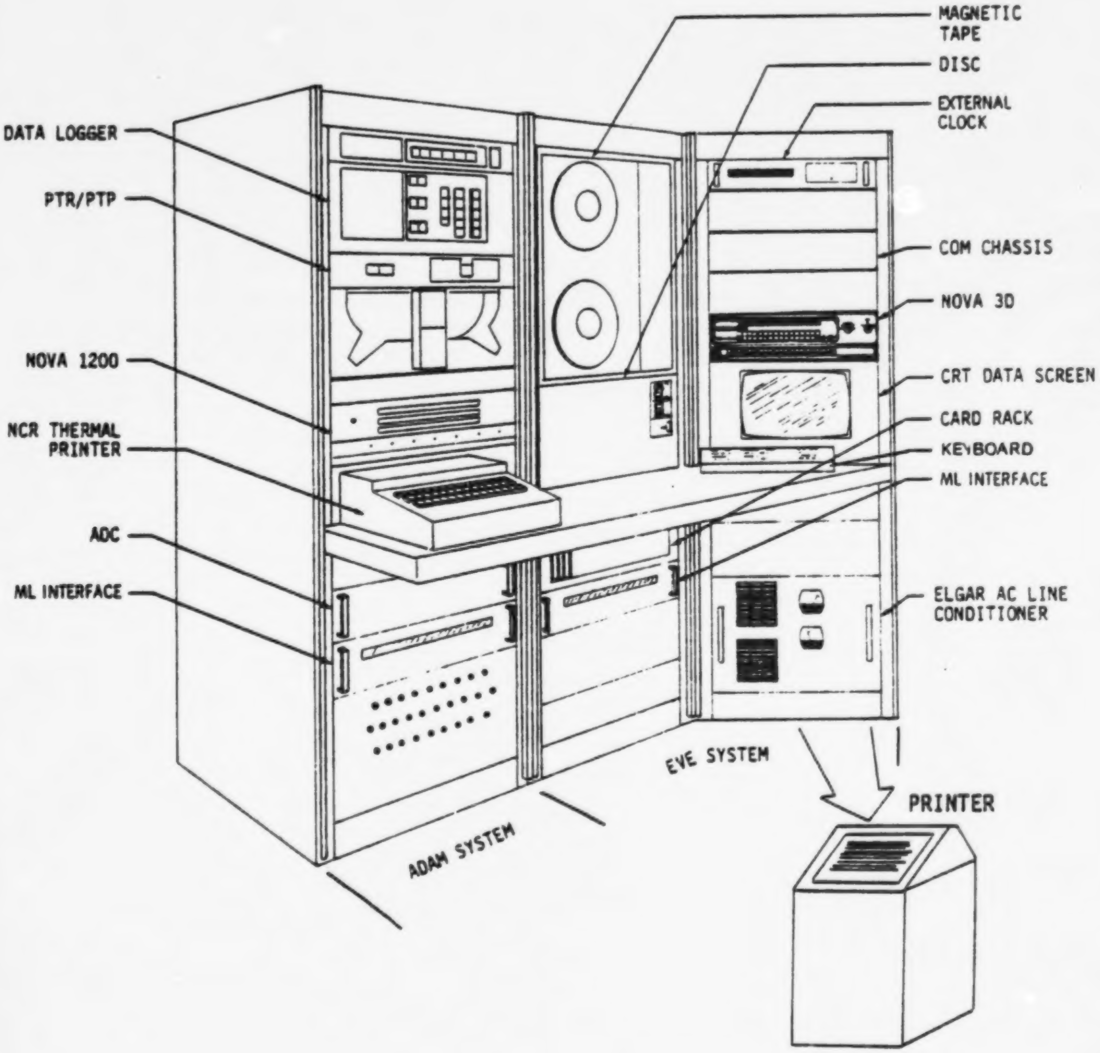

MAGNETIC TAPE
DISC
EXTERNAL CLOCK
DATA LOGGER
PTR/PTP
COM CHASSIS
NOVA 3D
NOVA 1200
CRT DATA SCREEN
CARD RACK
NCR THERMAL PRINTER
KEYBOARD
ML INTERFACE
ADC
ML INTERFACE
ELGAR AC LINE CONDITIONER
EVE SYSTEM
PRINTER
ADAM SYSTEM

Figure 11 WMS Computer System

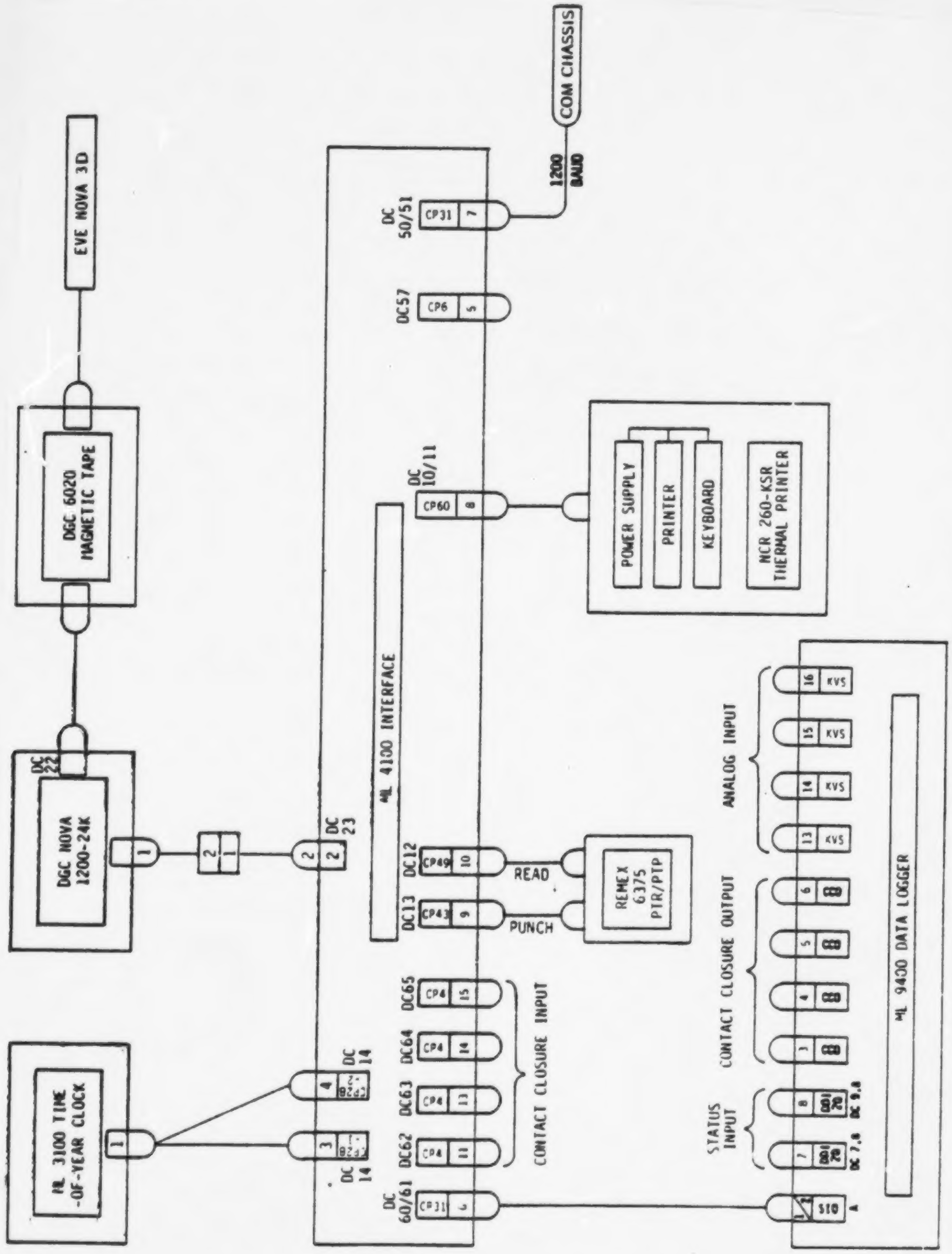

ML 3100 TIME -OF-YEAR CLOCK
1
DGC NOVA 1200-24K
1
DC 22
DGC 6020 MAGNETIC TAPE
EVE NOVA 3D
2
1
DC 23
2
ML 4100 INTERFACE
DC 14
DC 14
3
4
CP28
DC 60/61
CP31
6
DC62
DC63
DC64
DC65
CP4
11
13
14
15
CONTACT CLOSURE INPUT
DC13
CP43
9
DC12
CP49
10
PUNCH
READ
REMEX 6375 PTR/PTP
DC 10/11
CP60
8
POWER SUPPLY
PRINTER
KEYBOARD
NCR 260-KSR THERMAL PRINTER
DC57
CP6
5
DC 50/51
CP31
7
1200 BAUD
COM CHASSIS
STATUS INPUT
CONTACT CLOSURE OUTPUT
ANALOG INPUT
S10
A
7
8
DC 7,8
DC 9,A
1
4
5
6
13
14
15
16
KVS
ML 9400 DATA LOGGER

Figure 12 ADAM System Configuration

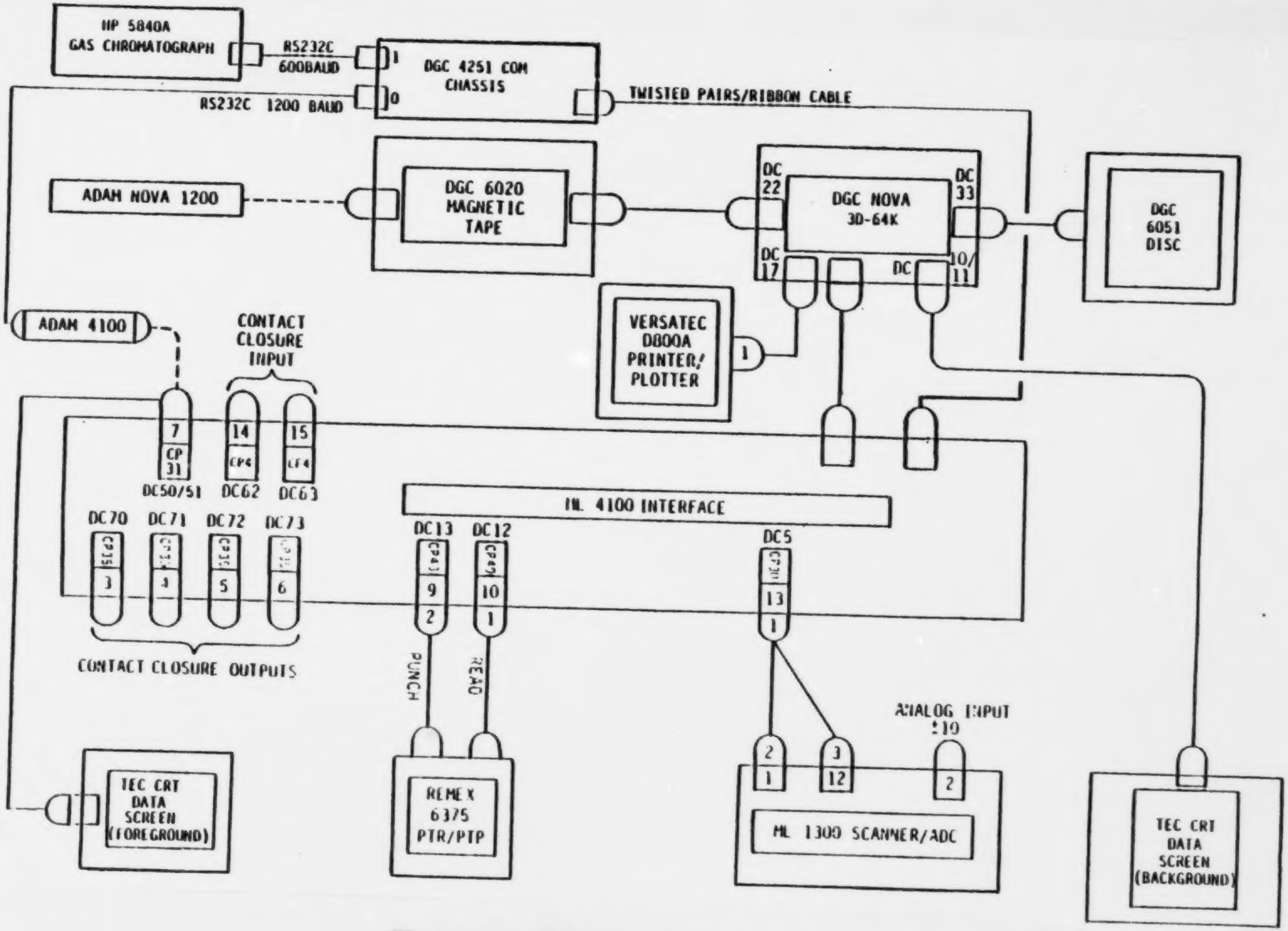

HP 5840A GAS CHROMATOGRAPH
RS232C 600BAUD
RS232C 1200 BAUD
1
0
DGC 4251 COM CHASSIS
TWISTED PAIRS/RIBBON CABLE
ADAM NOVA 1200
DGC 6020 MAGNETIC TAPE
DC 22
DC 17
DGC NOVA 3D-64K
DC 33
DC
10/ 11
DGC 6051 DISC
VERSATEC D800A PRINTER/ PLOTTER
1
ADAM 4100
CONTACT CLOSURE INPUT
7
CP 31
DC50/51
14
CP4
DC62
15
DC63
IN 4100 INTERFACE
DC70
DC71
DC72
DC73
CP35
3
4
5
6
CONTACT CLOSURE OUTPUTS
DC13
CP43
9
2
PUNCH
DC12
10
1
READ
DC5
13
1
TEC CRT DATA SCREEN (FOREGROUND)
REMEX 6375 PTR/PTP
2
1
3
12
ANALOG INPUT ±10
2
ML 1300 SCANNER/ADC
TEC CRT DATA SCREEN (BACKGROUND)

Figure 13 EVE System Configuration

data reports provide the previous 1 minute value, and the previous 15 minute, 30 minute, and hourly averages as well as the running average for each of the 40 available channels. Historical data reports provide the hourly averages for each hour of any day on record. Daily reports provide daily averages and instantaneous and hourly peak values and the time of day each occurred. Both hourly averages and daily averages may be plotted simultaneously with data processing and display.

The computer operating manual with a detailed software description is contained in Reference 1.

PERFORMANCE EVALUATION

The true measure of performance by developmental systems, such as the WMS, is the contribution made toward producing effective operational systems. This means that problem areas are uncovered and possible solutions are tested before commiting the design of operational systems.

Much experience has been accumulated from WMS operations. Solutions to some identified problems are yet unresolved due to practical constraints (time and money). Available resources to date have been allocated primarily to functional considerations including the understanding of sensor characteristics (standardization requirements, interferences, data collection and validation), and software development to support a variety of potential data applications (sensor and system control, treatment process characterization, and plant process control). Reconfiguring the system to totally eliminate data errors and minimize downtime has received lower priority attention.

Predicting performance of some future operational system in terms of availability, reliability and O&M costs of an existing preprototype setup is approximate, at best, and is subject to misinterpretation. Nonetheless, such data are presented in the following paragraphs. The reader should recognize that this information contains measured performance of production hardware (commercial sensors) as well as preprototype systems (biological analyzers, GC analyzer, and computer software) whose production configurations have not yet been established and tested.

Hardware age contributed to the failure frequency. The biological sensors, for example, contain some NASA surplus hardware, primarily valves, which are approximately 10 years of age. The age of most of the commercial sensors is about 4-5 years or less.

Sample Collection and Distribution System

The sample collection and distribution system was used to collect and distribute samples from six locations which included water of a quality ranging from City of Palo Alto final effluent to tertiary treated wastewater. The system worked very well throughout the test period. Fifty micron-woven stainless steel filters were used for filtration purposes for the test period. The filters are .08 cm thick and 10 cm in diameter. Two filters are located in the filter housing and are both used concurrently. Because of the high flow rate of sample across the filter surface and the backflushing action, the system had no difficulty removing particles and debris from the sample stream. What did present a problem was grease contained in the City of Palo Alto effluent during the last part of July and the first part of August. Also during the same time period, the high amount of lime present in effluent from the flocculator/clarifier also clogged the filters. During July, a malfunction in the reclamation facility resulted in the filters becoming clogged with carbon fines. In order to prevent a loss of sample flow during this problem period, the normal procedure of cleaning the filters on Monday, Wednesday, and Friday was modified to clean the filters five times a week. Figure 2 shows the flow schematic for the system.

The only persistent problem that occurred during the test period was the buildup of debris in the pump recirculation valve which resulted in increased sample flow and the introduction of air bubbles to the sample. One backflush cylinder and control relay failed during the test period. Four sample valves failed also during the test period. Additionally, the main sample pump had to be rebuilt because of a bearing failure.

Chemiluminescence Biosensor

The chemiluminescence biosensor currently processes and measures total and viable bacteria once during each 1-hour period. Typical values measured in the various wastewater effluents monitored by the WMS are illustrated in Figure 14. The sensor is routinely calibrated using a Coulter electronic particle counter and the firefly luciferase - ATP assay for total and viable bacteria, respectively.

The biosensor mechanically and electronically operated satisfactorily during the test period. There were, however, several minor problems encountered during this time. The flow cell became clogged with precipitant from the reagents. This problem was solved by disassembling and flushing the flow cell. The drain line became clogged with calcium carbonate and had to be replaced. Several pilot valves and the diaphragm in the compressed air pressure regulator failed and had to be replaced.

Correlation of the viable bacteria results of the biosensor presents special problems. Various values for viable bacteria can be obtained depending on the type of method employed. Each method measures a particular parameter associated with viability. The ATP method and luminol - CO method are measures of metabolism while the standard plate count method is a measure of the ability of a cell to reproduce and form colonies in an artificial environment. For this reason the luminol method cannot be expected to produce the same results as the plate counts. The ATP results have shown correlation with the luminol data; however, it is known that ATP levels within bacteria can fluctuate depending on environmental conditions and growth phase. For this reason, the ATP method can be used for "ball park" comparison and some deviations should be expected, the most consistent correlation occurs with the Coulter electronic particle counter.

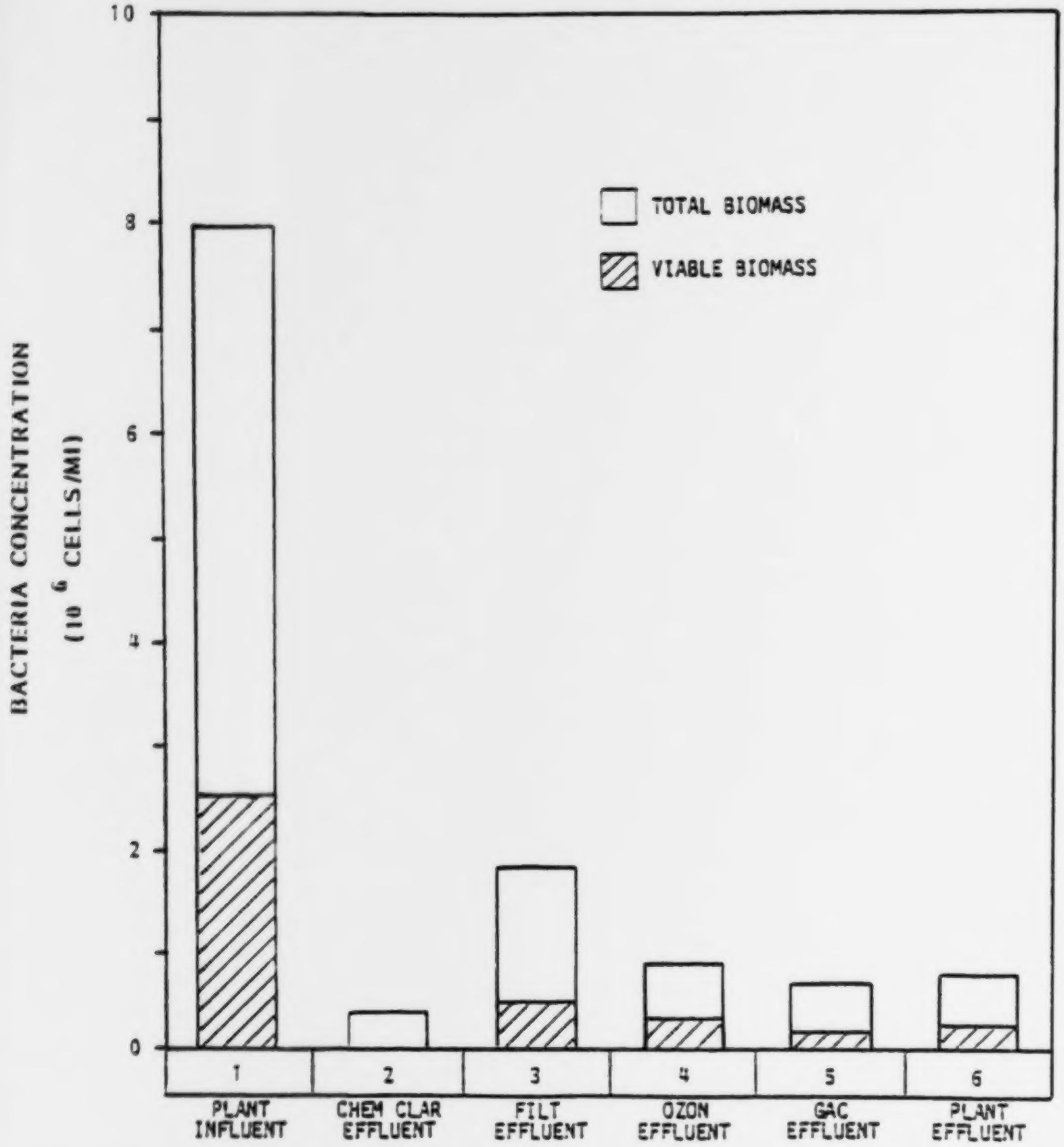


Figure 14 Total and Viable Bacteria Levels in Various Waste-Water Effluents

Gas Chromatograph

The GC operated quite well during the first part (July through September) of the test period. However, early in October, the preparatory columns lost carrier gas flow for several hours because of a malfunction of the shutoff valve on the carrier gas cylinder. As a result, the two preparatory columns began exhibiting an excessive amount of column bleed, which totally masked the compounds being monitored. Efforts to reduce the column bleed by baking out the columns at above normal operating temperatures were unsuccessful. Two new preparatory columns were ordered to allow the analyzer to be put back on line as soon as possible. However, when the new preparatory columns arrived and were installed, they showed a high baseline signal. Procedures to reduce the baseline signal were immediately started. The procedures called for raising the operating temperature of the preparatory GC to increasingly higher temperatures (from 105°C to 150°C) and injecting ultrapure water into the preparatory columns to reduce the baseline to a usable level. This procedure was extremely time consuming. The baseline was determined to be at a usable level just prior to shutting the WMS down for the Christmas holidays. The Bendix automatic injector was found to be leaking air into the sampling chamber during the column bakeout period. Replacement parts were ordered and the injector rebuilt. The preparatory column oven and the analytical oven were shut down for the Christmas holidays, and both carrier gases were allowed to continue flowing. It was believed that this would prevent the columns from becoming contaminated; however, when the GC ovens were brought back up to operating temperature the columns showed extreme column bleed. Once again, the lengthy process of baking out the columns was begun. This process was still underway at the end of the test period. As a result, the GC only collected data for the months of July, August, and September. This fact is reflected in a very low availability.

Total Organic Carbon Analyzer

The new low temperature ultraviolet light TOC analyzer was operational for the test period. Overall the analyzer worked quite well. Stability and response time were greatly improved over the old high temperature unit. Overall maintenance time was reduced considerably. The analyzer was modified to allow for computer-controlled automatic calibration. This system consisted of two Teflon air-actuated slider valves, two pilot valves, and two microswitches.

Several problems did occur during the test period. The first problem encountered was that the sparging system was not removing all of the inorganic carbon from the sample. This problem was corrected by adding 9.1 m of 0.5 cm inside diameter tubing to increase the contact time for conversion of inorganic carbon to CO_2. Additionally, a change was made in the TOC calibration curve in the ADAM minicomputer. Two separate pump tubing failures occurred. The first of these was in the sample pump and resulted in some erroneous data. The second failure took place in the pump leading to the ultraviolet light reaction chamber. This was much more serious as it allowed the ultraviolet lamp to overheat and subsequently two of the three lamps failed. The water separator and sparger assembly developed a significant crack and had to be replaced.

Hardness Analyzer

The operation of the analyzer was hampered by one persistent problem. The analyzer was found to be very susceptible to interferences from residual chlorine levels above 0.5 mg/l. The interference effect would cause the analyzer to show excessively high (400-1,000 mg/l) values. Additionally, the high amount of lime being added in the reclamation chemical clarification process flash mixer in July and August resulted in lime accumulation in the electrode chamber. The reagent tubing in the reagent container periodically clogged with debris suspended in the reagent container. With these exceptions, the analyzer's overall performance was good during the test period. The hardness analyzer is extremely expensive to operate in terms of labor and materials costs.

Nitrate Analyzer

The nitrate analyzer's operation during the test period was limited. The main cause of the problem was the extremely high level of nitrate in the City of Palo Alto effluent. In July it was found that the analyzer was reading 9 mg/l on a sample having a lab verified value of 19 mg/l. The apparent cause was that above 9 mg/l the colormetric system was unable to differentiate darker shades of blue. A decision was made to order a new autodiluter system to return the color of the sample to a usable level. The new diluter took over 6 weeks to arrive from the manufacturer since it is a nonstock item. Once the new metricone was installed, an effort was made to immediately calibrate the analyzer and put it back on line. However, at that point a problem was discovered with the transmission of the sensor status and data signal to the ADAM minicomputer. This problem was finally resolved after several weeks of troubleshooting. Once again, an attempt was made to put the analyzer back on line. However, it was found that the sensor would not stay in calibration for more than a few hours of operation. The manufacturer was contacted in an effort to resolve this problem. It is believed that the high levels of nitrate in the samples were causing the cadmium in the reduction chamber to become spent very quickly. The test period ended before a lasting fix was found for this problem.

pH Analyzer

The Great Lakes Instrument Model 70 pH Analyzer provided good, reliable data. The sensor required calibration on an average of once a month during the test period. There wasn't any serious fouling of the probe as a result of sampling secondary effluent or the high lime content in the clarifier effluent. When the probe was removed for calibration, the electrode was checked for any accumulations of foreign material. The electrode tip was cleaned in a 0.1 N acid solution if a significant accumulation was found. For calibration, a pH standard of 7 was first used; followed by a pH standard of 10 to check the slope.

Total Residual Chlorine Analyzer

Overall the analyzer operated very well and provided reliable data throughout the test period with a minimum of problems. The only lengthy downtime the analyzer encountered was due to the unavailability of the needed reagent from the manufacturer. The manufacturer has apparently worked out a new production schedule to resolve this problem. The analyzer is fairly expensive to operate in terms of routine maintenance and consumables.

Sodium Analyzer

The Beckman Sodium Analyzer provided good data throughout the test period. However, the analyzer's flow system repeatedly clogged during the test period. This and the need to refill the zero and span standard containers on a daily basis require a high number of man-hours of effort each week. It has been found that it is necessary to disassemble and clean the flow system once a week with dilute hydrochloric acid. This is because the anhydrous ammonia used in the analyzer causes the particles in the sample to clump and settle in the flow system. The anhydrous ammonia is necessary to adjust the pH level of the sample prior to introducing it to the electrode chamber. A problem was encountered with the gravity flow system that feeds electrolyte to the analyzer's reference electrode. A pressurized system was installed and the problem resolved, except for one occasion when the reference electrode tip clogged. This was resolved by placing the tip in boiling deionized water.

Temperature Analyzer

The analyzer provided good reliable data throughout the test period except during the last week of operation when the Action-Pac amplifier failed. Additionally, the socket to which the amplifier is attached was replaced at the beginning of the test period. The probes' output was checked once each month against that from a glass thermometer inserted into the sample stream.

Turbidity Analyzer

The Sigrist Photometer Turbidimeter worked extremely well throughout the entire test period. The analyzer provided excellent data with a minimum of routine or unscheduled maintenance. The only component which failed during the test period was the replaceable light source. The only routine maintenance required by the instrument was a once-a-week cleaning of the mirror in the flow cell and a check of the calibration. The TJ25 flow cell was used throughout the test period.

Coliform Detector

Prior to the beginning of the test period, the coliform detector was reworked to the four-broth, four-buffer cell configuration as previously described. This change significantly enhanced the capability of the detector to eliminate false positive reactions caused by noncoliform bacteria. These changes were necessitated when it was discovered that several noncoliform bacteria strains found in the Reclamation Plant effluent were capable of imitating the electrode response generated by coliform bacteria.

The majority of the effort expended on the coliform detector was divided between testing the new sensor configuration and solving an internal contamination problem which will be discussed in this section.

Specially selected samples of coliform and noncoliform bacteria and mixtures of the two were tested in an extensive effort to prove the validity of the buffer cell principle. When evaluating each experiment, a 200 mv change in the buffer cell electrode was accepted as evidence of coliform growth in the nutrient cell. The buffer cells repeatedly showed negative reactions for the noncoliform bacteria strains that were producing positive reactions in the broth cells. Based on these results, it was determined that the proper operating procedure is to use the millivolt output of the buffer cells to determine the presence of coliform bacteria and to use the broth cells millivolt output results to determine the initial coliform concentrations. As an example, if the broth and buffer cells showed positive results, the time required for the broth cells to show a 200 mv change would be plotted on the calibration curve to determine the initial coliform concentration. In all instances, this additional criterion was sufficient to allow for differentiation between coliform and noncoliform samples. Consequently, the reconfiguration of the coliform sensor has been deemed a success in dealing with the problem of false positives.

One major problem that surfaced during testing of the coliform sensor was that of internal bacterial contamination. The contamination problem was evidenced by the fact that on numerous occasions a sample which was known to be sterile showed growth in the nutrient cells. It was concluded that a significant population of bacteria was surviving the sensor's normal sterilization process and resided internally within the sensor at various times. Repeated washing and flushing of the sensor with various bacteriocides reduced but did not permanently eliminate the problem.

Presently, it is believed that the contaminating bacteria have been residing either within the sensor's pneumatic valve parts or inside the Teflon lines leading to the cells. As the sliding parts of the valves began to wear and their tolerance increased, small pools of nutrient and previous samples were discovered within the valves. In many instances, the leaks were not visible from the outside of the valves until the problem was well advanced. It is also thought that a bacterial and protein matrix may have been built up inside the sensor's tubing. In either case, the proposed solution for the contamination problem is a routine schedule of replacement for the coliform sensor's internal parts. It is believed that this action, along with close monitoring of internal valve tolerances, would alleviate the contamination problem.

In conjunction with the samples mentioned thus far, more than 20 samples of reclaimed effluent were tested for coliform concentrations. No positive reactions were observed in any of the reclaimed water samples. Correlating MPN tests substantiated the coliform results. It should be noted that the permissible number of coliforms in finished reclaimed effluent is 2.2/100 ml while the lower confidence limit for the coliform sensor is approximately 10/100 ml.

Mechanically, the coliform sensor operated very well during the test period. The few instances of component failure can be attributed to the sensor's age as it had seen more than 4 years of continuous service prior to the test period. It is believed that the parts that failed did so because they had reached the end of their useful lives. The following component failures were encountered during the test period:

1. Several PVC fittings on the hot water tank failed and were replaced with stainless steel.
2. Two temperature control boards failed during the test period. In each instance a single capacitor failed and was replaced.
3. Two electrodes began to give erratic readings and were replaced.
4. Several of the pneumatic valves began to leak fluids. In each instance new bushings were installed and the valve fittings were readjusted.

Table 5 shows the number of false positives which occurred during the test period. The data show that out of 48 broth cell tests made with Reclamation Plant effluent there were 8 false positive reactions. For the same samples there were zero false positive from the buffer cells. The results are even more impressive for the City of Palo Alto secondary effluent samples. Based on these data, the broth/buffer cell configuration appears to have successfully resolved the problem of false positive reactions caused by noncoliform bacteria.

TABLE 5

COMPARISON OF COLIFORM FALSE POSITIVES

	Reclamation No. of False Positives	Effluent Reliability	Secondary No. of False Positives	Effluent Reliability
Broth Cells	8/48	83.3%	19/40	53.3%
Buffer Cells	0/48	100.0%	0/40	100.0%

Ammonia Analyzer

The analyzer provided reliable data during the majority of the test period; however, several problems did occur which hampered operation. One problem which occurred repeatedly was air bubbles blocking sample flow in the gravity feed system. This was determined to be a flaw in the design of the analyzer. The metricone motor failed in July 1980, as did the signal amplifier unit. A problem with the colorimetric system was found in February 1981. The proper color change was not taking place in the flow system. The problem was traced to the pH value of the sodium hypochlorite reagent which was below the acceptable range of 7-8. The pH was adjusted upwards and the analyzer calibrated. The procedure for preparation of the reagent was modified to verify the pH of the sodium hypochlorite before preparing the reagent.

The analyzer is equipped with the WMS autostandardization system and was automatically calibrated once each day. Because of the frequency of reagent preparation the analyzer was quite labor intensive.

Conductivity Analyzer

The Beckman analyzer performed throughout the test period without any significant problems. Periodically the flow cell was removed from the flow system and checked for buildup on the cell walls. The values were routinely compared with the two conductivity analyzers in the laboratory at the reclamation facility.

Dissolved Oxygen Analyzer

The Delta Scientific analyzer performed reliably throughout the test period without any major problems. One Teflon electrode membrane failure occurred. The calibration of the analyzer was routinely checked using a Hach wet chemistry dissolved oxygen kit.

Deionized Water System

The system reliably provided high quality deionized water to the various parts of the WMS. The one problem which periodically occurred was bacteria contamination in the reverse osmosis storage tanks. As a result of this contamination it was necessary to sanitize the entire system once every 30 days. The RO60 reverse osmosis cartridge was found to have a useful life of 6 months with the available tap water. This is approximately one-half the expected useful life. The recommended procedure for storing the reverse osmosis cartridge during an extended shutdown period calls for shutting off the tap water flow to the cartridge and placing it in a formaldehyde solution. This procedure did not seem to work satisfactorily for the 2 week shutdown at Christmas. It was found that the best procedure was to leave the tap water flowing and run the effluent from the cartridge to the drain.

Data Acquisition and Report Generation System

Numerous hardware failures occurred for both computer systems during the test period. Some were hard failures and could easily be traced to printed circuit boards for the peripheral device control interfaces such as A/D, terminals and the magnetic tape unit. In addition, one computer memory board failure occurred on the average of every 3 months. Other failures were intermittent and could not be isolated to either software or hardware when one of the computers would halt. On the average, one failure occurred every week that resulted in approximately 16 hours downtime, although normally 8 hours per week can be expected.

Except for one software error in the NOVA 3D operating system that produced intermittent computer halts throughout the test period and was corrected in February 1981, all the failures could be traced to the hardware. A substantial number of failures were directly the result of poor electrical contacts. This problem may have been aggravated by the instances of chlorine gas entering within the WMS trailer when the WRF/PA had an equipment failure. The computer equipment is approaching the limit of its useful lifetime and can be expected to fail more frequently.

Some downtime was associated with software development activities during August 1980 and cannot be realistically charged to equipment availability. Also, the failures in January 1981 were the direct result of the equipment being turned off during the last 2 weeks of 1980. If these times are not considered, the average downtime is reduced to 5.5 hours per week.

WMS Availability

WMS availability (percent of time the subsystems/sensors operated on demand) was monitored during the test period. The operating time and downtime periods for each of these are summarized in Table 6. The downtime recorded for each of the sensors/subsystems includes actual repair times and downtime attributed to waiting for necessary reagents or parts.

WMS Reliability

Sensor/subsystem reliability (percent of operating time the data generated were valid) is summarized in Table 6. These values are calculated based on the number of hourly averages determined to be erroneous divided by the total number of hourly averages recorded. This calculation was made for each individual sensor/subsystem.

WMS Operations and Maintenance Costs

This section deals with the operations and maintenance costs for each of the sensors/subsystems. This is intended to cover all consumables, hardware and labor required for 8 months of continuous operation. This cost estimate is based on actual expenses incurred during the test period and as such may vary depending on the age of the hardware. An additional goal of the program was to determine, when possible, the life expectancy of the various subsystems. These data where available are reported in Appendix D.

The O&M costs for the sensors/subsystems of the WMS are summarized in Table 7. Extrapolation of these data gives a projected annual O&M cost of $94,125.

The distribution of costs may be summarized as follows:

	Labor	Materials	Total
Operations	18.0%	4.9%	22.9%
Maintenance	57.6%	19.5%	77.1%
Total	75.6%	24.4%	100.0%

These calculations are based on the detailed data contained in Appendix D. Appendix D additionally contains a list of the recommended spares for each sensor/subsystem.

TABLE 6

AVAILABILITY/RELIABILITY

WMS OPERATING ELEMENTS	DOWN TIME (HRS)/ OPERATING TIME (HRS)/	(%) AVAILABILITY	ERRONEOUS DATA (HRS)/ TOTAL DATA (HRS)	(%) RELIABILITY	SIGNIFICANT PROBLEM(S)
Sampling System	11/3931	99.7	246/3916	94.5	Periodic Plant Process Upsets
Computer System	551/4454	87.6	371/3903	90.5	Printed Circuit Board Failures
Biosensor	171/3633	95.3	110/3418	96.8	None
Coliform Detector	17[1]/97[1]	82.5	0/88	----	Contamination and Hardware Failures
TOC	355/3553	90.0	148/3111	95.2	Failure of UV Lamps
Residual Chlorine	870/3672	76.3	15/2994	99.5	Temporary Unavailability of Reagent
Turbidity	1/3739	99.9	4/3737	99.9	None
D.O.	2/3729	99.9	20/3724	99.5	None
Ammonia	267/3324	92.0	448/3055	85.3	Pump and Valve Failures, Reagent Problems
Nitrate/ Nitrite	3366/3587	6.2	39/221	82.4	Cadmium Reduction System Malfunction
pH	3/3764	99.9	48/3744	98.7	None
Conductivity	0/3770	100.0	3/3753	99.9	None
Temperature	38/3762	99.0	11/3719	99.7	Corrosion of Contacts in Socket
Hardness	84/3504	97.6	1249/3420	63.5	Interference of Residual Chlorine

TABLE 6 (Continued)

Sodium	100/3689	97.3	259/3591	92.8	Buildup of Debris in Electrode Holder
G.C.	2613/3635	28.1	100/1022	90.2	Column Bleed in Preparatory G.C.
D.I. Water	271/5447	95.0	0/5282	----	None
A.C. System[2]	3/5832	99.9	0/5756	----	None

NOTE:

[1] Coliform Detector Operations and Downtime Reported in Days.

[2] A. C. System is a dual unit, each independent of the other.

TABLE 7

OPERATIONS AND MAINTENANCE COST OF WATER MONITOR SYSTEM

JULY 1, 1980 THROUGH FEBRUARY 23, 1981

	1/ Operations	Maintenance	Totals
Sampling System			
Materials and Supplies	$ 340	$ 220	560
Labor	300	190	490
Computer System			
Materials and Supplies	1070	2230	3300
Labor	4140	13600	17740
Biosensor			
Materials and Supplies	180	240	420
Labor	450	2080	2530
Coliform Detector			
Materials and Supplies	300	470	770
Labor	2900	3070	5970
Gas Chromatograph			
Materials and Supplies	200	670	870
Labor	1380	4500	5880
TOC Analyzer			
Materials and Supplies	790	940	1730
Labor	340	860	1200
Residual Chlorine Analyzer			
Materials and Supplies		1480	1480
Labor	70	1370	1440
Turbidity Analyzer			
Materials and Supplies		60	60
Labor	60	110	170
Dissolved Oxygen Analyzer			
Materials and Supplies		100	100
Labor	30	110	140
Ammonia Analyzer			
Materials and Supplies		790	790
Labor	570	4320	4890
Nitrate/Nitrite Analyzer			
Materials and Supplies		960	960
Labor	220	1500	1720
pH Analyzer			
Materials and Supplies		50	50
Labor	60	220	280
Conductivity Analyzer			
Materials and Supplies			
Labor		110	110
Temperature Analyzer			
Materials and Supplies		130	130
Labor	20	110	130

TABLE 7 (Continued)

Hardness Analyzer			
Materials and Supplies		1950	1950
Labor	140	1830	1970
Sodium Analyzer			
Materials and Supplies	200	150	350
Labor	400	1890	2290
Deionized Water System			
Materials and Supplies		1370	1370
Labor	240	270	510
General Lab Supplies		400	400
TOTALS	$14,400	$48,350	$62,750

Projected Yearly O&M Cost = $94,125

1/ NOTE:

Labor costs of $37/hr. for engineering; $27/hr. for all others.

2/ NOTE:

Includes operator time for implementing new software.

Summary

As previously mentioned, the purpose for developmental systems is to identify problems before committing to the design of an operational system. The experience with the WMS has shown that the following will be key considerations when building reliable and inexpensive operational systems:

1. The ideal sensor: is an electrode; can be located in the sample; requires no reagents; is not subject to interference from other constituents in the sample; is fail-safe; i.e., it fails in a readily identifiable manner; is easily maintained; is rugged; has proven reliability in a variety of applications; resists fouling by solids or grease; is stable for long periods without calibration; does not require sample preconditioning, i.e., filtering, concentration, fixed flow rate, etc.; does not require complex electronics for control or signal conditioning; provides a direct continuous readout of a controllable parameter. Most water quality sensors do not meet all these specifications. Some conductivity cells and dissolved oxygen electrodes which are available on the market meet many of these requirements. Most other sensors introduce complexities which must be managed.

2. Colorimetric procedures and gravity flow through small tubing should be avoided in unattended automated sensor applications.

3. Operators should be trained to understand the significance of each measurement and the failure modes of the sensors. Competent vendors will provide such detailed information on the characteristics of their sensors. The comprehensiveness of the vendor's operating manual is often a good indicator of the quality of the product.

4. Sensors utilizing proprietary reagents should be avoided unless a contracted delivery schedule is prearranged.

5. The system design should provide fault detection, alarm, and alternate operating modes for significant failure modes:

    a. Loss of sample.

    b. Air in sample (where it interferes with the analyses).

    c. Loss of sensor sensitivity, i.e., reagent, sample, etc.

    d. Filter plugging.

    e. Erroneous data.

6. Automatic standardization is a necessary requirement for unattended operation of most chemical sensors.

7. Computer systems hardware and software should be provided with error detection and correction capability. The ability to detect and correct single bit errors in the computer main memory can substantially increase reliability.

8. Direct memory access or high speed I/O channel programs should be provided when communicating with other computer systems. This will allow data to be transferred directly into main memory rather than a less reliable transfer by an applications program via a low speed device, i.e., RS232.

9. Dial-up/auto-answer communications provide the capability for remote failure diagnosis. Troubleshooting thereby can be accomplished without specialists being retained on-site.

DATA PROCESSING

In addition to the real-time data display and trend plotting, the EVE report generation system has data processing capability for a lognormal distribution analysis and a linear regression analysis. A lognormal distribution was chosen to interpret the data obtained from monitoring based on the study performed by McCarty, et al, at Stanford University (reference 3). The Stanford study evaluated parameters for several probability models using various sets of organic and inorganic concentration data from Water Factory 21 in Orange County, California. Models for normal and lognormal probability distributions were selected for analysis because they produced reasonable data fits and provided ease of statistical interpretation. It was concluded that the lognormal distribution adequately represented the results at least 92% of the time and thus provided an adequate description of the probability for organic and inorganic materials at Water Factory 21. (The lognormal distribution was rejected for only ammonia and conductivity.)

Verification of the validity of the lognormal distribution is provided in the Stanford study, and no attempt was made to consider other probability models for this study. The lognormal distribution has a strong theoretical justification based on the assumption that fluctuations are proportional rather than additive. The chi square statistic was determined for each parameter as a method to evaluate the validity of the lognormal distribution and determine if the data were normally distributed. The results indicate a high correlation exists for most parameters.

A linear regression analysis was performed on all monitored data to evaluate the relationship between parameters across the reclamation plant and among processes. The least-square line obtained by the linear regression allows a determination of the standard error of estimate and the coefficient of correlation and thus provides a means of evaluating the direct dependence of the variables.

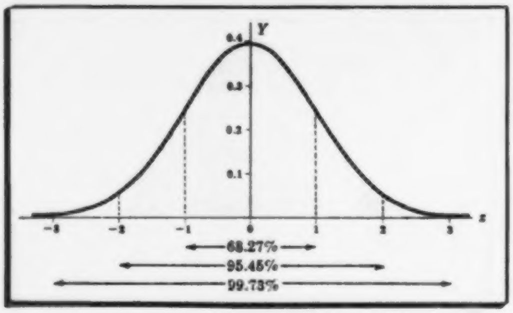
Characteristics of the Lognormal Distribution

Normally distributed data will plot as a straight line on probability paper if the ordinate scale is arithmetic, while lognormally distributed data will plot as a straight line if the ordinate scale is logarithmic. Normal distribution is one of the most important examples of continuous probability distribution and is defined by the following equation (reference 6):

$$Y = \frac{1}{\sigma\sqrt{2\pi}} e^{-(X-\mu)^2/2\sigma^2}$$

Where μ = mean, σ = standard deviation, and X is expressed in standard units with $Z = (X-\mu)/\sigma$

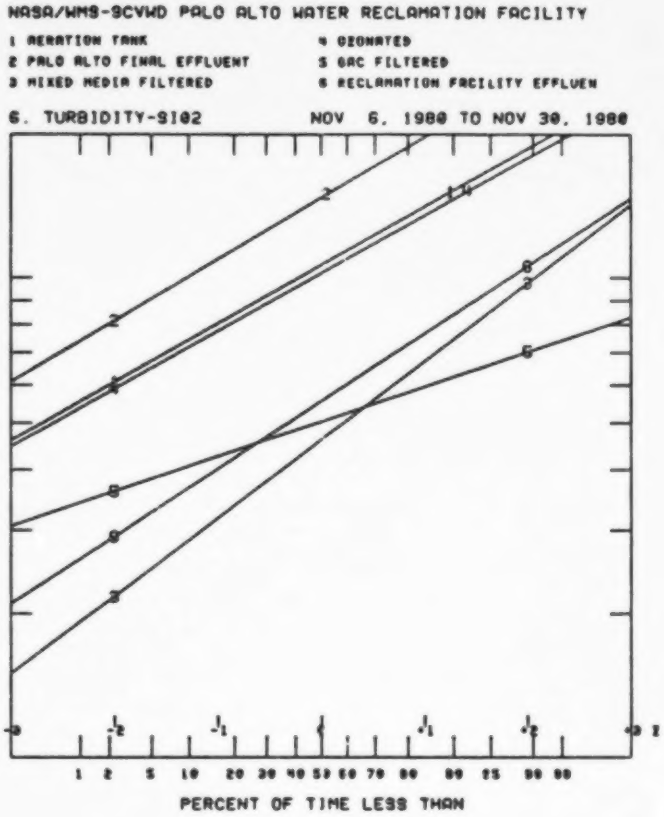
In such cases, Z is normally distributed with mean zero and variance 1. A graph of the standardized normal curve is shown below with the areas included between Z = -1 and +1, Z = -2 and +2, and Z = -3 and +3 as equal to 68.27%, 95.45%, and 99.73% of the total area under the curve which is one.



In order to analyze a set of data, the average and standard deviation of the logs are determined by common statistical procedures. The average so obtained represents the intercept, and the standard deviation represents the slope of the regression line for the lognormal distribution.

Computer plots of these results were generated for each parameter and for each period of interest. A representation of a typical result is shown in the following figure. The ordinate presents the log over the data range and the abscissa presents the percentage of time the total population was less than the measured value. The Percent of Time Less Than corresponds to the probability of occurrence for a measured value. The data range represents the daily average obtained from the hourly average which was determined from sample rates of 1 minute for all measurements with the exception of the G.C. and biomass measurements, which were recorded once each hour.

It should be noted that in the heading, on the following figure, the reclamation plant influent (Palo Alto final effluent) is sample source #2 and not #1. This is because prior to this test period, sample source #1 was primary effluent, and the aeration tank was not a sampling point. Since a large amount of data had been collected and stored on computer tape, it was decided to leave the Palo Alto final effluent as sample source #2 so as not to hinder statistical analysis of the historical data.



SAMPLE SOURCE	MONTHLY AVERAGE	ONE SIGMA	LOG(Y)=F(Z)		SAMPLE SIZE
			SLOPE	INTERCEPT	
1	0.1108E 2	0.3194E 1	0.1215E 0	0.1024E 1	15
2	0.1526E 2	0.4261E 1	0.1273E 0	0.1167E 1	16
3	0.5034E 1	0.2904E 1	0.1632E 0	0.8642E 0	16
4	0.1055E 2	0.2295E 1	0.1203E 0	0.1010E 1	16
5	0.5094E 1	0.8363E 0	0.7243E -1	0.7013E 0	16
6	0.5048E 1	0.2033E 1	0.1403E 0	0.7442E 0	22

The Z-score is also shown on the abscissa for comparison. The 50% or zero value for Z represents the geometric mean. This plot is a good example of the waterfall decrease in the dependent variable across each process and readily shows the range of data for the report period.

The normal distribution function Q(x) is defined by Hasting's best approximate equation (reference 7),

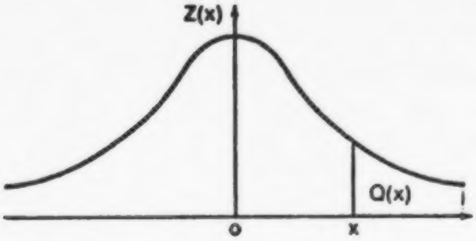
$$Z(x) = \frac{e^{-x^2/2}}{\sqrt{2\pi}}$$

$$Q(x) = Z(x)[b_1t + b_2t^2 + b_3t^3 + b_4t^4 + b_5t^5]$$

$$t = \frac{1}{1 + px}$$

$p = .231642$ $b_3 = 1.78148$
$b_1 = .319382$ $b_4 = -1.82126$
$b_2 = -.356564$ $b_5 = 1.33027$

where Q(x) = area under the standardized normal curve from 0 to +Z



The test for normality or goodness of fit is based on the X^2 (chi square) distribution at the 95% confidence level for 2 degrees of freedom,

$$X^2_{.95} = 5.99 \text{ (based on Z being a function of } \mu \text{ and } \sigma\text{)}$$

$$\text{where } \chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

f_o = observed or actual frequency

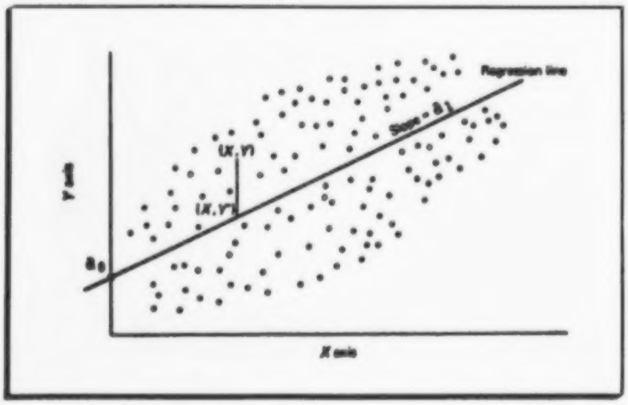
f_e = estimated frequency based on a normal distribution

The chi square statistic has been calculated for each parameter at each sample point to evaluate the goodness of fit to the postulated lognormal distribution. There is only one chance in twenty of chi square exceeding 5.99 if the data are normally distributed. Thus, the lognormal distribution model may be rejected with 95% confidence when the value exceeds 5.99. Much of the data presented in this report is adequately described by a lognormal distribution, however, there are exceptions, as shown in Appendix A.

Characteristics of the Linear Regression

In a linear regression analysis, values of the dependent variable are predicted from a linear function of the form

Where Y' is the estimated value of the dependent variable Y; the constant a (referred to as the Y intercept) is the point at which the regression line crosses the Y axis and represents the predicted value of Y when X = 0; and the constant a (usually referred to as the regression coefficient) is the slope of the regression line and indicates the expected change in Y with a one-unit change in X (reference 7).



The regression method involves the evaluation of a_0 and a_1 in such a way that the sum of the squared residual is smaller than any possible alternative values, i.e.;

$(Y - Y')^2 = \text{minimum}$
where $Y - Y'$ = residual or difference between the actual and estimated value of Y for each case

The optimum values of a_0 and a_1 are obtained from

$$a_1 = \frac{\Sigma(X - \overline{X})(Y - \overline{Y})}{\Sigma(X - \overline{X})^2} = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{N\Sigma X^2 - (\Sigma X)^2}$$

$$a_0 = \overline{Y} - a_1\overline{X} = \frac{(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)}{N\Sigma X^2 - (\Sigma X)^2}$$

The Standard Error of Estimate is a measure of the accuracy of the prediction equation. It is the standard deviation of actual Y values from the predicted Y' values or

$$\sigma_E = \text{Standard Error} = \sqrt{\frac{\Sigma(Y - Y')^2}{N - 2}}$$

The Standard Error is interpreted as the "average residual."

The linear correlation coefficient is the ratio of the explained variation to the total variation or

$$r = \sqrt{\frac{\text{explained variation}}{\text{total variation}}} = \sqrt{\frac{\Sigma(Yest - \overline{Y})^2}{\Sigma(Y - \overline{Y})^2}}$$

where Yest = estimated value obtained from linear regression

$\overline{Y}$ = average of dependent variable

Y = dependent variable

and is determined by

$$r = \frac{m\sqrt{\sigma x}}{\sqrt{\sigma y}}$$

where m = slope of regression line

σx = standard deviation of independent variable

σy = standard deviation of dependent variable

Results of the regression analysis for the report periods are presented in Appendix A. Linear ($Y = a_0 + a_1 X$), parabolic ($Y = a_0 + a_1 X + a_2 X^2$), and logarithmic ($\log Y = a_0 + a_1 \log X$) regressions were performed for each parameter across each process and across the reclamation plant. Results indicate that linear and logarithmic regressions generally provide a good prediction for the downstream parameter. In some cases, particularly for the halocarbons and total organic carbon, the logarithmic regression produced a superior improvement in the correlation coefficient compared to the linear and parabolic regressions.

A typical example of a statistical summary and regression analysis is shown in Tables 8 and 9. The monthly average is determined from the hourly averages. The daily average variation is the standard deviation of the daily averages. The hourly average variation is the standard deviation of the hourly averages. The percent removal is determined from

$$\% \text{ removal} = \frac{I - 0}{I} \times 100\%$$

where I = influent value

0 = effluent value

for sample source 1 to 6 across the plant. The percent removal across each process is determined from

$$\% \text{ removal} = \frac{(I - 0)\text{process}}{(I - 0)\text{plant}} \times 100\%$$

where (I-0)plant = measured concentration removal across the plant

(I-0)proccess = measured concentration removal across the process

In this manner, the removal efficiency of each process can be compared for the plant.

TABLE 8 SAMPLE STATISTICAL DATA

```
STATISTICAL DATA FOR SEP  3, 1980 TO FEB 28, 1981


SAMPLE SOURCE 1 = PALO ALTO SECONDARY EFFLUENT

CHA      SENSOR       UNITS     SAMPLING   MONTHLY  DAILY AVG  HOURLY AVG
                                FREQUENCY  AVERAGE  VARIATION  VARIATION

 1. TOTAL BIOMASS MIL C/ML         97        2.016     1.1199     1.7654
 2. VIABLE BIOMASSMIL C/ML         99        0.559     0.3026     0.5906
 5. RES CHLORINE  MG/L             91        4.034     1.9418     2.8983
 6. TURBIDITY-SIO2MG/L            114       13.858     5.1524     5.9096
 7. DIS OXYGEN    MG/L            114        6.167     1.8291     1.9818
10. AMMONIA       MG/L             88        5.141    10.1695    13.4274
11. NITRATE       MG/L
12. PH            PH              115        5.601     0.4526     0.5157
13. TOT ORG CARBON MG/L            96        9.742     2.4224     2.8073
14. CONDUCTIVITY  MMMHO/CM        115     1234.413    62.6263   110.6204
15. TEMPERATURE#1 DEG F           114       71.576     2.4593     3.4832
16. HARDNESS      MG/L             80      327.246   338.3398   390.5041
17. SODIUM        MG/L            108      158.729    12.6491    16.5998
20. AMBIENT TEMP  DEG F           123       73.063     1.7708     3.0392
29. TOT HALOCARBON PPB             29       92.881   117.4967   159.5066


SAMPLE SOURCE 6 = RECLAMATION FACILITY EFFLUENT

CHA      SENSOR       UNITS     SAMPLING   MONTHLY  DAILY AVG  HOURLY AVG    PERCENT REMOVAL
                                FREQUENCY  AVERAGE  VARIATION  VARIATION   DAILY AVG STD DEV

 1. TOTAL BIOMASS MIL C/ML        115        0.295     0.4231     0.8168       85.38   26.53
 2. VIABLE BIOMASSMIL C/ML        116        0.141     0.3947     0.6423       74.84  120.17
 5. RES CHLORINE  MG/L            104        2.022     1.1813     2.1562       49.88   47.73
 6. TURBIDITY-SIO2MG/L            138        4.682     1.7975     3.9064       66.22   18.61
 7. DIS OXYGEN    MG/L            138        6.191     1.6235     1.6985       -0.39   34.39
10. AMMONIA       MG/L             97        4.215    12.7591     8.1426       18.01   79.43
11. NITRATE       MG/L
12. PH            PH              138        6.080     0.5129     0.4489       -8.55    8.87
13. TOT ORG CARBON MG/L           106        3.750     1.3529     1.2533       61.51   15.05
14. CONDUCTIVITY  MMMHO/CM        138     1313.281    65.5476    75.7599       -6.39    5.09
15. TEMPERATURE#1 DEG F           137       71.301     1.7635     1.9501        0.00    0.00
16. HARDNESS      MG/L             89      390.219   306.4944   332.9858      -19.24   83.13
17. SODIUM        MG/L            130      153.705    13.3527    15.5863        0.00    0.00
20. AMBIENT TEMP  DEG F           147       73.149     2.2023     2.6701        0.00    0.00
29. TOT HALOCARBON PPB             28      106.872   103.9368   164.2026      -15.06   52.13

EOF..
```

Reproduced from
best available copy.

TABLE 9 SAMPLE REGRESSION ANALYSIS

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS             A0          A1      STANDARD     CORR.       SAMPLE
NO.                                                         ERROR      COEFF.       SIZE

 1. TOTAL BIOMASS MIL C/ML        0.2141      0.0408      0.4055      0.1124          92
 2. VIABLE BIOMASSMIL C/ML        0.1577     -0.0368      0.3941      0.0291          93
 5. RES CHLORINE  MG/L            1.7591      0.0312      1.0366      0.1402          87
 6. TURBIDITY-SIO2MG/L            4.4161      0.0015      1.4865      0.1627         109
 7. DIS OXYGEN    MG/L            2.6872      0.5467      1.1081      0.6637         109
10. AMMONIA       MG/L           -1.0724      1.0158      4.6056      0.8964          75
11. NITRATE       MG/L            0.0000      0.0000      0.0000      0.0000           0
12. PH            PH              4.0657      0.3535      0.4693      0.3327         110
13. TOT ORG CARBON MG/L           1.5039      0.2310      1.3211      0.3777          87
14. CONDUCTIVITY  MMMHO/CM      551.0430      0.6210     56.2356      0.5751         110
15. TEMPERATURE#1 DEG F          30.3830      0.5749      1.1896      0.7684         109
16. HARDNESS      MG/L          175.3407      0.6246    238.5027      0.7185          56
17. SODIUM        MG/L           49.4841      0.6630      8.4651      0.6913         104
20. AMBIENT TEMP  DEG F          20.7091      0.7181      1.0060      0.7813         119
29. TOT HALOCARBON PPB           15.9887      0.9306     20.5553      0.9720          22

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS             A0          A1          A2      STANDARD     CORR.
NO.                                                                     ERROR      COEFF.

 1. TOTAL BIOMASS MIL C/ML        0.1043      0.1523     -0.0216      0.4032      0.1547
 2. VIABLE BIOMASSMIL C/ML        0.1541     -0.0222     -0.0113      0.3941      0.0294
 5. RES CHLORINE  MG/L            1.2779      0.2694     -0.0242      1.0254      0.2019
 6. TURBIDITY-SIO2MG/L            2.1270      0.3504     -0.0117      1.4407      0.2923
 7. DIS OXYGEN    MG/L            4.2649     -0.0540      0.0517      1.0877      0.6789
10. AMMONIA       MG/L           -0.2078      0.6453      0.0088      4.5438      0.8993
11. NITRATE       MG/L            0.0000      0.0000      0.0000      0.0000      0.0000
12. PH            PH             -8.6666      4.4506     -0.3235      0.4266      0.5146
13. TOT ORG CARBON MG/L           7.3318     -0.8341      0.0456      1.2102      0.5297
14. CONDUCTIVITY  MMMHO/CM    -3142.5810      6.6745     -0.0025     53.3058      0.6314
15. TEMPERATURE#1 DEG F        -129.0141      4.9116     -0.0294      1.0343      0.8310
16. HARDNESS      MG/L          -37.9160      1.5098     -0.0004    205.3962      0.7941
17. SODIUM        MG/L         -279.7527      4.7522     -0.0126      8.0106      0.7297
20. AMBIENT TEMP  DEG F         151.2825     -2.8758      0.0247      1.0012      0.7837
29. TOT HALOCARBON PPB           19.3210      0.8472      0.0002     20.4795      0.9722

LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS             A0          A1      STANDARD     CORR.
NO.                                                         ERROR      COEFF.

 1. TOTAL BIOMASS MIL C/ML       -0.6996      0.2628      0.2508      0.4833
 2. VIABLE BIOMASSMIL C/ML       -1.0099      0.3956      0.3897      0.6575
 5. RES CHLORINE  MG/L            0.0674      0.2346      0.2836      0.3904
 6. TURBIDITY-SIO2MG/L            0.4968      0.1155      0.1314      0.3497
 7. DIS OXYGEN    MG/L            0.4108      0.4661      0.0880      0.6431
10. AMMONIA       MG/L           -0.1634      0.8047      0.3558      0.8683


11. NITRATE       MG/L            0.0000      0.0000      0.0000      0.0000
12. PH            PH              0.4867      0.3927      0.0308      0.3939
13. TOT ORG CARBON MG/L           0.2524      0.3075      0.1325      0.2588
14. CONDUCTIVITY  MMMHO/CM        1.3144      0.5839      0.0188      0.5659
15. TEMPERATURE#1 DEG F           0.7571      0.5917      0.0071      0.7682
16. HARDNESS      MG/L            0.9152      0.6520      0.1850      0.6922
17. SODIUM        MG/L            0.6393      0.7043      0.0234      0.7036
20. AMBIENT TEMP  DEG F           0.5609      0.6994      0.0060      0.7618
29. TOT HALOCARBON PPB            0.0769      1.0003      0.1527      0.9806
```

SECTION 5

SANTA CLARA VALLEY WATER DISTRICT - WATER RECLAMATION FACILITY AT PALO ALTO

DESCRIPTION

General

The SCVWD Palo Alto Reclamation Facility is a pilot facility designed to treat 0.09-m^3/s (2 mgd). Figure 15 shows the basic processes in the Reclamation Facility, which has as an influent the chlorinated, nitrified, filtered secondary effluent from the 1.53-m^3/s (35 mgd) Regional Water Quality Control Plant located in Palo Alto. The reclamation plant includes the following: High-lime treatment, single-stage recarbonation, breakpoint chlorination for further nitrogen removal, mixed-media filtration, activated carbon sorption with carbon regeneration, ozonation, chlorination for disinfection, and storage. Innovative design of the plant allows flexibility in the sequence of the unit processes. For instance, the water can be filtered prior to or after activated carbon treatment, or both, depending on the need to protect the carbon beds or to eliminate carbon fines in the effluent. This flexibility was provided to permit research and testing of various alternatives prior to building a larger plant.

The facility has a direct digital computer control system that allows operators to alter control parameters. Process configurations are easily changed by the engineering staff. The computer supplies operational data to personnel on shift, while operating the plant.

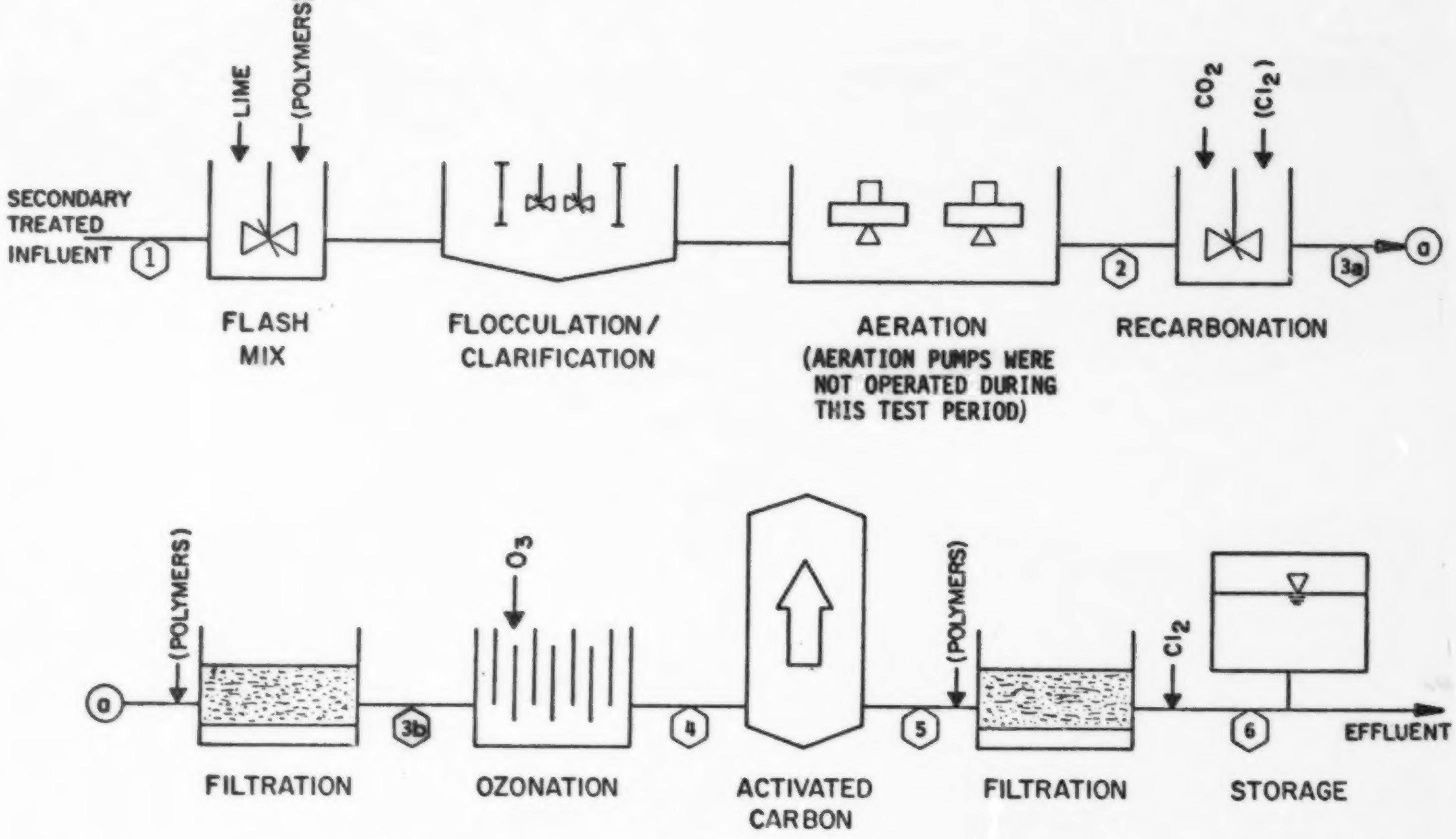
The following are general descriptions of the processes. Table 10 describes capacity parameters for the processes.

Control and Instrumentation

A Modcomp II/221 computer with 64K words of main memory, two moving head disk drives with 2.6M words of memory, one fixed head disk with 512K words of memory, one REMAC multiplexer unit, three CRT's, a card reader, and a printer are utilized for plant data acquisition and control. The software utilized is a modified version of a standard control package called FLICK.

All instruments in the plant, as listed on Table 11, are standard commercially available devices.

The need for exceptional process flexibility (i.e., arranging unit processes in any desired order) led to the selection of a DDC (digital data control) system with no conventional analog backup control. It was felt that such


SECONDARY TREATED INFLUENT
1
LIME
(POLYMERS)
FLASH MIX
FLOCCULATION / CLARIFICATION
AERATION
(AERATION PUMPS WERE NOT OPERATED DURING THIS TEST PERIOD)
2
CO_2
(Cl_2)
RECARBONATION
3a
a
a
(POLYMERS)
FILTRATION
3b
O_3
OZONATION
4
ACTIVATED CARBON
5
(POLYMERS)
FILTRATION
Cl_2
6
STORAGE
EFFLUENT

⬡ CURRENT SAMPLE POINT

NOTES:

1. MAXIMUM OF SIX SAMPLE POINTS ACTIVE AT ONE TIME
2. PARENTHESIS INDICATE CHEMICAL FEED CAPABILITY NOT CURRENTLY UTILIZED

Figure 15 Santa Clara Valley Water District Reclamation Facility at Palo Alto

a hardwired backup, as found in many plants, would restrict process flexibility to an unacceptable extent. Also, because of the "pilot" nature of this plant a backup computer system was not justifiable. Because of the lack of a backup system, outages due to the control system were much more frequent than would be experienced in a conventional plant where usual backup and redundancy measures were utilized.

Chemical Clarification

Chemical treatment is effective in removing suspended solids, colloidal solids, and some dissolved constituents, such as heavy metals and phosphates. During the initial periods of operation, removal of ammonia by air stripping was implemented for the reclamation system. Therefore, since this process requires a high pH, lime was selected as the chemical of choice. A secondary benefit was achieved, since the high pH resulting from additional lime is also considered to be quite effective in pathogen destruction.

The process consists of separate rapid mix, flocculation, and sedimentation basins. Lime is added in a slurry form to the rapid mix basin. The feed rate is automatically controlled to achieve the optimum pH of approximately 11. The dose to achieve this pH was 100 to 200 mg/l as calcium oxide. The water flows from the bottom of the flash mix basin to a center column in the flocculator clarifier. The influent enters the center column of the tank at its bottom, rises up the center column, and comes out through the side openings at the column near the top. The flocculation basin contains two flocculating mixers within a circular mixing compartment. These provide complete mixing so as to develop a substantial rapid settling floc. After mixing and blending, the influent exits from the bottom of the flocculating compartment and flows radially outward in the clarification compartment. Heavier solids resulting from the process settle to the bottom of the tank. The tank's effluent passes over a weir into a shallow trough around the periphery of the tank.

TABLE 10

SCVWD-WRF/PA UNIT PROCESS CHARACTERISTICS

AT 0.09 m^3/s (2 MGD)

Flash Mix

Lime Feed Capacity:	2700 kg/day (3 tons/day)
Process Volume:	15.9 m^3 (560 cu. ft.)
Mixer Horsepower:	5 hp
Detention Time:	3 minutes

Flocculator/Clarifier

Type:	Center Feed, Peripheral Weir, Circular
Diameter:	16.8 meters (55 feet)
Depth:	3.4 meters (11 feet)
Flocculator Detention Time:	0.5 hr.
Clarifier Detention Time:	1.9 hr.

TABLE 10 (Continued)
SCVWD-WRF/PA UNIT PROCESS CHARACTERISTICS

Aeration (Ammonia Stripping) - Aeration pumps were not operated during this test period.

Tank Dimensions:	16.8 m L x 9.1 m W x 4.3 m D (55 ft. L x 30 ft. W x 14 ft. D)
No. of Aerators:	2
Combined Horsepower:	100 hp
Circulation Fan Horsepower:	30 hp
Detention Time:	2.1 hr.

Recarbonation

Tank Dimensions:	6.4 m L x 2.1 m L x 2.1 m W x 4.2 m D (21 ft. L x 7 ft. W x 13.75 ft. D)
Mixer Horsepower:	10 hp
Stack Gas Feed Capacity:	550 SCFM
Detention Time:	11 minutes

Ozonation

Tank Dimensions:	6.4 m L x 2.1 m W x 4.1 m H (21 ft. L x 7 ft. W x 13.5 ft. H)
Ozonator Capacity:	42.6 kg/day (94 lb/day)
Detention Time:	10.5 minutes

Filters*

Number of Filters:	4
Type:	Mixed Media
Surface Area (each):	20.5 m^2 (221 sq. ft.)
Media Depth:	0.9 m (3 ft.)
Hydraulic Loading:	7.1 $m^3/sec/m^2$ (3.1 gpm/sq. ft.)

Granular Activated Carbon

Number of Columns:	4
Type:	Upflow
Diameter:	3.0 m (10 ft.)
Bed Depth:	6.1 m (20 ft.)
Total Carbon Volume:	177.8 m^3 (6280 cu. ft.)
Carbon Type:	Calgon Filtrasorb 300 (8 X 30 mesh)
Hydraulic Loading:	10.1 $m^3/sec/m^2$ (4.4 gpm/sq. ft.)
Empty Bed Contact Time:	34 minutes

*Filters may be assigned to pre-GAC and post-GAC filtration in any combination. Hydraulic loading value given is for two filters on each service.

TABLE 11

PLANT INSTRUMENTATION

INSTRUMENT TYPE	NUMBER	INSTRUMENT TYPE	NUMBER
Flow	10	Dissolved Oxygen ppm	1
Level	19	Sludge Density %	1
Pressure psi	5	Tachometer RPM	1
Temperature C^{O}	4	Analog Output Test % Max	1
Turbidity FTU & NTU	6	Valve Monitor % Open	18
pH	3	Valve Monitor % Closed	2
Conductivity MHO	1	Pump Monitor % Max	5
Residual Chlorine ppm	1		

The results of lime clarification at Palo Alto have shown this process to be effective in reducing turbidity, organics, suspended solids and heavy metals.

Recarbonation

Following settling, the effluent flows through an open tank, formerly used for air stripping, into the recarbonation basin for adjustment of the pH. Stack gas from the existing sludge incineration furnaces of the Palo Alto Regional Water Quality Control Plant is transferred to the recarbonation basin. The stack gas, providing the carbon dioxide source, and the liquid are thoroughly mixed by a flash mixer before leaving the chamber. A sediment trap is provided for removal of contaminants from the stack gas before it enters into the blower. The pH in the recarbonation chamber is automatically controlled by the in-plant computer and determines the amount of stack gas needed and automatically adjusts the opening at the motorized gas inlet valve to provide the proper recarbonation pH. During the test period, this pH was selected to be 7.0.

Mixed-Media Filtration

The recarbonated effluent is then pumped to two open gravity multimedia filter basins designed for a hydraulic loading rate of 7.1 $m^3/sec/m^2$ (3.1 gpm/ft^2). The purpose of the mixed-media filtration is additional removal of suspended solids and floc carried over from preceding steps. Filtration is performed prior to granular activated carbon sorption since the possibility of fouling by suspended solids and colloidal matter exists. The filter media are 910 cm (36 inches) deep and consist of coarse coal, sand, and garnet supported by a layer of sand and garnet gravel.

Ozonation

Following mixed-media filtration, the flow is directed to an ozonation chamber. Ozonation was provided to evaluate its effectiveness for enhanced disinfection and trace organics removal. The ozonation system consists of an ozonator, diffusers and baffles. Ozone is an unstable form of oxygen, which is produced in nature when oxygen in the atmosphere is exposed to an electrical discharge, such as lightning. It is also produced artificially, as in an ozonator, by passing clean, dry air through electrodes when high-voltage electrical discharges occur. The ozonator is capable of generating 42.6 kilograms (94 pounds) of ozone at 1% minimum concentration in 24 hours.

Granular Activated Carbon Sorption

From the ozone chamber, the water is pumped to the carbon towers, and flows upward through the diffusers at the underdrain plate of the carbon column. Effluent discharges through the collection lauders located near the top of the towers. Each tower is 3.0 meters (10 feet) in diameter, 9.1 meters (30 feet) in overall height, and contains a 6.1 meter (20 foot)-high column of granular activated carbon. All four carbon towers are identical. The contactors operate in parallel, each having an empty bed contact time of 34 minutes. The hydraulic loading rate for each column is 10.1 $m^3/sec/m^2$ (4.4 gpm/sq ft). Following GAC sorption, the flow is diverted through the other two mixed-media filters. The purpose here is to remove any carbon fines that may have washed over the tower weirs. Finally, chlorine is added to provide a residual of about 1 mg/l and then the flow is directed to a storage tank for future use.

PLANT/PROCESS PERFORMANCE EVALUATION

WMS data on the operating characteristics of the plant were collected beginning in 1978 through February 1981. During that 3-year timeframe the plant has operated in various configurations, which are summarized in Table 12. The table shows that changes have occurred to plant influent processing as well as to in-plant configurations.

This report was originally intended to describe the steady-state performance of the plant beginning in July 1980 through the end of February 1981. As shown in Table 12 the reclamation plant influent, effluent from the secondary treatment process, changed during this period from that for which the reclamation plant was originally designed; i.e., activated sludge to fixed-film reactor (deep trickling or roughing filter)/nitrification/dual-media filtration. These changes were in the process of stabilization for much of the summer of 1980. Also, once stabilized, these changes had a substantial effect on concentration levels of certain water quality parameters in the reclamation plant influent.

Thus, in order to provide the desired steady-state performance data which are representative of plant capability, the results of two different periods, A and H, are presented. Plant and influent processing during these two test periods is shown in Table 12. In some respects, period H, even though only a

TABLE 12 PROCESS CONFIGURATIONS FOR TEST PERIODS

TEST PERIOD SYMBOL	TEST PERIOD	RECLAMATION PLANT INFLUENT PROCESSING							RECLAMATION PLANT PROCESSES								
		PRIMARY SETTLING	FIXED FILM REACTOR	AERATION (ACTIVATED SLUDGE)	AERATION (NITRIFICATION)	CLARIFICATION	DUAL MEDIA FILTRATION	CHLORINATION	CHEMICAL CLARIFICATION PH	AERATION	RECARBONATION	MIXED MEDIA FILTRATION	OZONE DOSAGE, MG/L	GAC UNIT	MIXED MEDIA FILTRATION	CHLORINE DOSAGE, MG/L	RECLAMATION PLANT FLOW, MGD
A	09/03/80 - 02/28/81	x	x		x	x	x	x	11	-	x	x	4	1,2,4	x	2	1.5
B	05/07/80 - 08/28/80	x	x		x	x	-	x	11	-	x	x	4	1,2,4	x	2	1.5
C	02/12/80 - 05/06/80	x	-	x		x	-	x	11	-	x	x	4	1,2,4	x	2	1.5
D	11/11/79 - 02/11/80	x	-	x		x	-	x	11	x	x	x	-	4	x	3	1.5
E	10/09/79 - 11/10/79	x		x		x	1/2 FLOW → 1/2 FLOW →		11	x	x	x	-	4	x	2	2.0
F	08/11/79 - 10/08/79	x	-	x		x	-	-	11	x	x	x	-	3,4	x	3	1.0
G	05/21/79 - 07/28/79	x	-	x		x	-	x	11	x	x	-	-	3,4	x	4	1.0
H	03/31/79 - 05/02/79	x	-	x		x	-	x	9.5	-	x	x	5	3,4	x	4	1.0
I	11/28/78 - 03/19/79	x	-	x		x	-	x	-	-	-	x	11	2	x	5	0.5

1-month period, may be more representative than period A of conditions normally present in tertiary treatment. The configuration differences of these two periods are summarized below:

Influent Processing	Period A	Period H
Activated Sludge		X
Fixed-Film Reactor/ Nitrification/ Dual-Media Filtration	X	
Granular Activated Carbon		
New		X
Exhausted	X	
Chemical Clarification		
pH 9.5		X
pH 11	X	

Presented below are plant and process input/output data for periods A and H, plant and process availability and O&M costs as measured for the 8-month period beginning July 1, 1980, through February 28, 1981, and plant reliability for the two test periods.

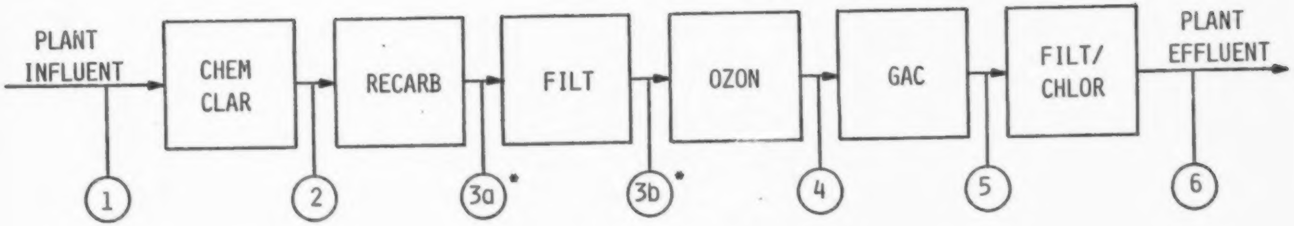
Input/Output

Figure 16 shows the location of sampling points in the process stream and the sampling schedule. Plant influent and effluent concentrations for the two test periods are summarized in Table 13. It should be noted that for period A, the pH of the influent was significantly lower because of nitrification at the city plant.

The percentage change in concentration across each of the processes is shown in Table 14. The change in a parameter as the water flows through each process can be followed horizontally, from left to right, for both test periods. Large negative values indicate that the process caused a significant reduction of this constituent. The overall effectiveness of each of the processes can be judged by examining the numbers vertically. It is readily apparent from this table that the chemical clarification and activated carbon sorption processes had the greatest influence on changes in water quality.

The results of a statistical analysis of process performance are presented for each WMS parameter in Figures 17 through 36. The upper graph compares plant input to output for the two test periods based on a lognormal distribution model and a ± 3 data range (99.7% of the data). The plot also shows

SAMPLING POINTS


PLANT
INFLUENT
CHEM
CLAR
RECARB
FILT
OZON
GAC
FILT/
CHLOR
PLANT
EFFLUENT
1
2
3a*
3b*
4
5
6

SAMPLING TIME ~ HOUR OF DAY

1	2	3a	3b	4	5	6
3	2	4	4	5	6	1
9	8	10	10	11	12	7
15	14	16	16	17	18	13
21	20	22	22	23	24	19

* SAMPLING POINT 3a WAS ACTIVE BEFORE JULY 11, 1980 (INCLUDING TEST PERIOD H).
SAMPLING POINT 3b WAS ACTIVE BEGINNING JULY 11, 1980 (INCLUDING TEST PERIOD A).

Figure 16 Sampling Schedule

TABLE 13 PLANT PERFORMANCE FOR TWO TEST PERIODS (GEOMETRIC MEAN)

		PERIOD A			PERIOD H		
		INFLUENT	EFFLUENT	% CHANGE	INFLUENT	EFFLUENT	% CHANGE
TOTAL BIOMASS	mc/ml	1.7	0.2	-87.2	13.8	2.4	-82.4
VIABLE BIOMASS	mc/ml	0.4	0.1	-84.0	3.1	0.2	-92.9
TOTAL RESIDUAL CHLORINE	mg/L	3.5	1.7	-53.0	9.5	1.9	-79.9
TURBIDITY	mg/L	12.9	4.4	-65.8	18.8	2.9	-84.4
DISSOLVED OXYGEN	mg/L	5.8	6.0	2.4	-	-	-
TOTAL ORGANIC CARBON	mg/l	9.4	3.6	-62.2	13.8	3.3	-76.4
AMMONIA	mg/l	2.4	1.3	-43.5	18.7	16.4	-12.7
NITRATE / NITRITE	mg/l	SENSOR NOT ON LINE					
pH	pH	5.6	6.1	8.5	7.0	7.2	2.7
CONDUCTIVITY	µmho/cm	1233.	1312.	6.4	1466.	1560.	6.4
HARDNESS	mg/l	269.	327.	21.3	367.	296.	-19.5
SODIUM	mg/l	158.	153.	-3.2	-	-	-
TETRACHLOROETHYLENE	µg/l	3.1	2.9	-6.7	51.6	3.6	-93.0
METHYLENE CHLORIDE	µg/l	16.7	10.0	-40.4	10.5	20.8	98.6
1,2-DICHLOROETHYLENE	µg/l	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROFORM	µg/l	11.5	23.1	100.4	24.5	4.9	-79.8
1,1,1-TRICHLOROETHANE	µg/l	1.5	3.4	125.1	21.8	1.3	-94.2
BROMODICHLOROMETHANE	µg/l	13.7	18.2	32.7	3.7	1.2	-67.0
TRICHLOROETHYLENE	µg/l	1.5	1.8	19.9	20.8	1.5	-92.7
DIBROMOCHLOROMETHANE	µg/l	7.4	12.9	73.9	1.5	1.1	-29.0
BROMOFORM	µg/l	0.0	0.0	0.0	1.7	1.3	-21.6
TRIHALOMETHANES	µg/l	33.4	57.0	70.6	31.7	8.3	-73.8
TOTAL HALOCARBONS	µg/l	62.1	77.4	24.7	191.0	38.4	-79.9

TABLE 14 PROCESS PERFORMANCE FOR TWO TEST PERIODS (GEOMETRIC MEAN)

CONCENTRATION CHANGE ACROSS PROCESS, % OF PLANT INFLUENT CONCENTRATION- △1

——— Period A
------- Period H

PROCESS SAMPLE POINTS		CHEM CLAR 1 → 2	CHEM CLAR/RECARB 1 → 3a	RECARB/FILT 2 → 3b	FILT/OZON 3a → 4	OZON 3b → 4	GAC 4 → 5	FILT/CHLOR 5 → 6
TOTAL BIOMASS	Period A	-91		22		-15	-	○
	Period H		-64		-19		○	-
VIABLE BIOMASS	Period A	-95		27		-14	-	○
	Period H		-75		-20		○	○
TOTAL RESIDUAL CHLORINE	Period A	-68		-		-	-15	42
	Period H		-52		○		-49	16
TURBIDITY	Period A	-26		-33		25	-27	-
	Period H		-41		○		-42	-
DISSOLVED OXYGEN	Period A	14		-		○	-10	-
	Period H							
TOTAL ORGANIC CARBON	Period A	-32		○		-	-27	-
	Period H		-13		-		-56	○
AMMONIA	Period A	-11		-17		-	-16	○
	Period H		○		-		-10	-
NITRATE / NITRITE								
pH	Period A	31		-24		○	-	-
	Period H		○		○		-	-
CONDUCTIVITY	Period A	4		○		○	○	○
	Period H		4		○		○	○
HARDNESS	Period A	-11		○		-	-	37
	Period H		-27		○		-21	24
SODIUM	Period A	-		○		○	-	○
	Period H							
TETRACHLOROETHYLENE	Period A	-17		68		-49	-	-10
	Period H		-53		-23		-17	-
METHYLENE CHLORIDE	Period A	-45		42		-19	-18	○
	Period H		-31		-10		141	-
1,2 - DICHLOROETHYLENE								
CHLOROFORM	Period A	59		-47		○	55	26
	Period H		-27		-		-52	○
1,1,1 - TRICHLOROETHANE	Period A	-29		-		○	136	23
	Period H		-75		-		-14	○
BROMODICHLOROMETHANE	Period A	55		-20		○	-	-
	Period H		-22		-		-44	○
TRICHLOROETHYLENE	Period A	-26		-		-	43	10
	Period H		-52		-16		-25	○
DIBROMOCHLOROMETHANE	Period A	58		-33		37	-40	52
	Period H		-		○		-28	○
BROMOFORM	Period A							
	Period H		27		-15		-39	○
TRIHALOMETHANES	Period A	58		-35		17	○	23
	Period H		-19		-		-51	○
TOTAL HALOCARBONS	Period A	14		-		○	○	10
	Period H		-54		-10		-16	○

NOTE:

1. A CIRCLE WITHOUT A NUMBER INDICATES THAT THE CHANGE IS NOT SIGNIFICANT; i.e., USUALLY LESS THAN 10%.

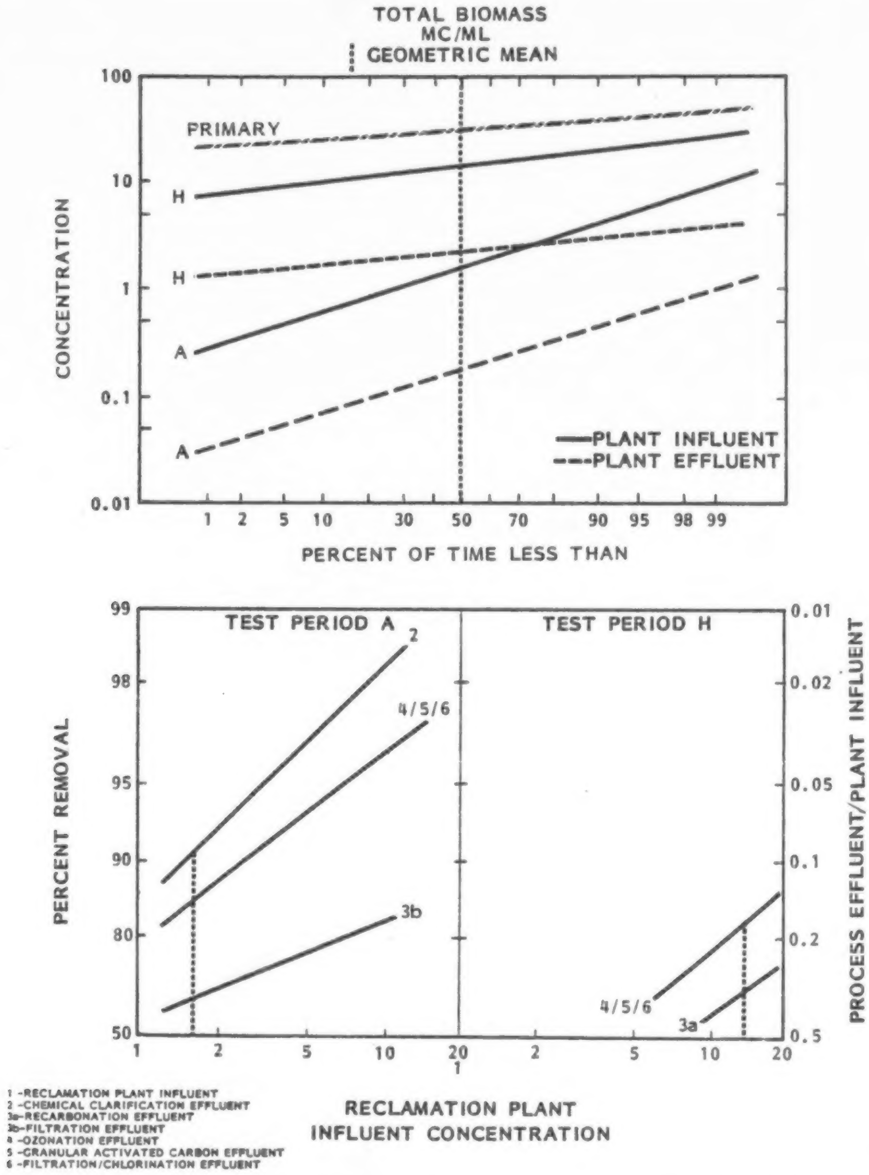


Figure 17 Data Distribution & Process Removal Characteristics

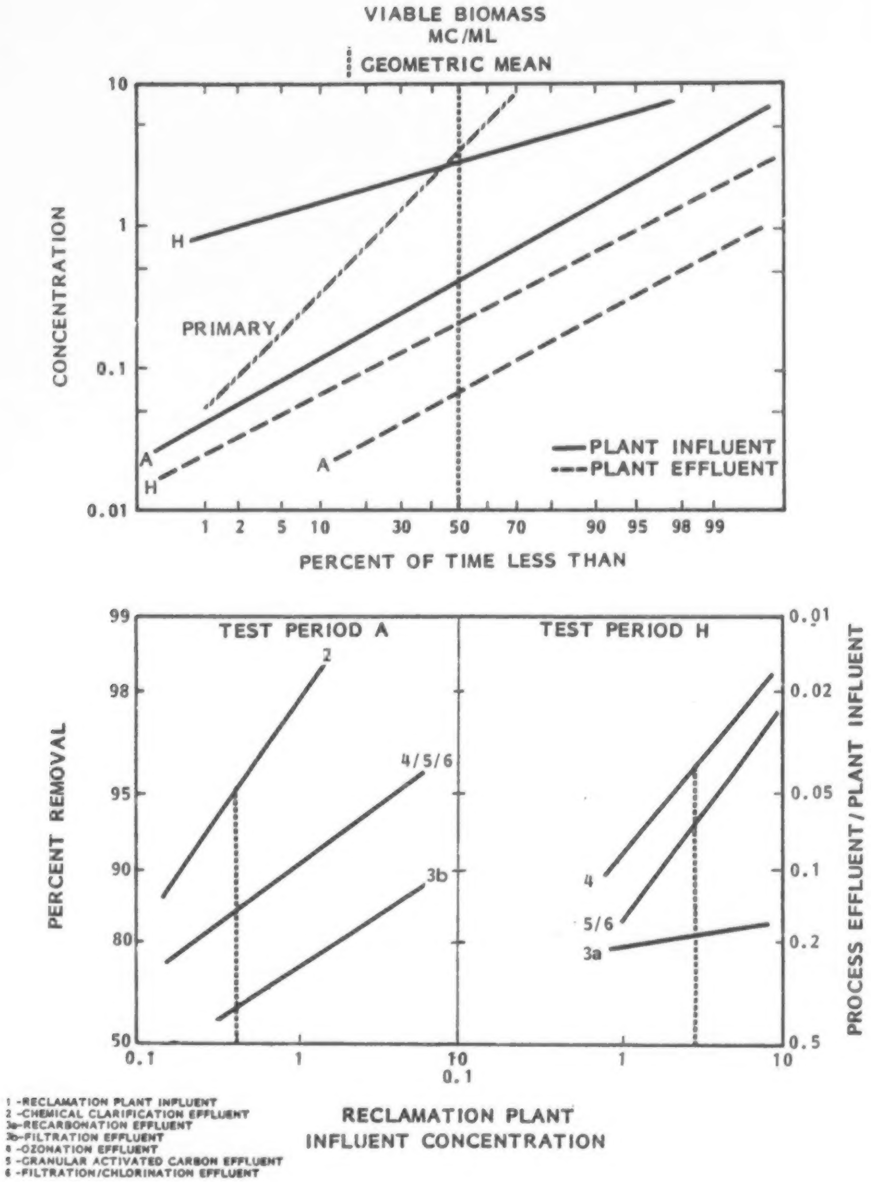


Figure 18 Data Distribution & Process Removal Characteristics

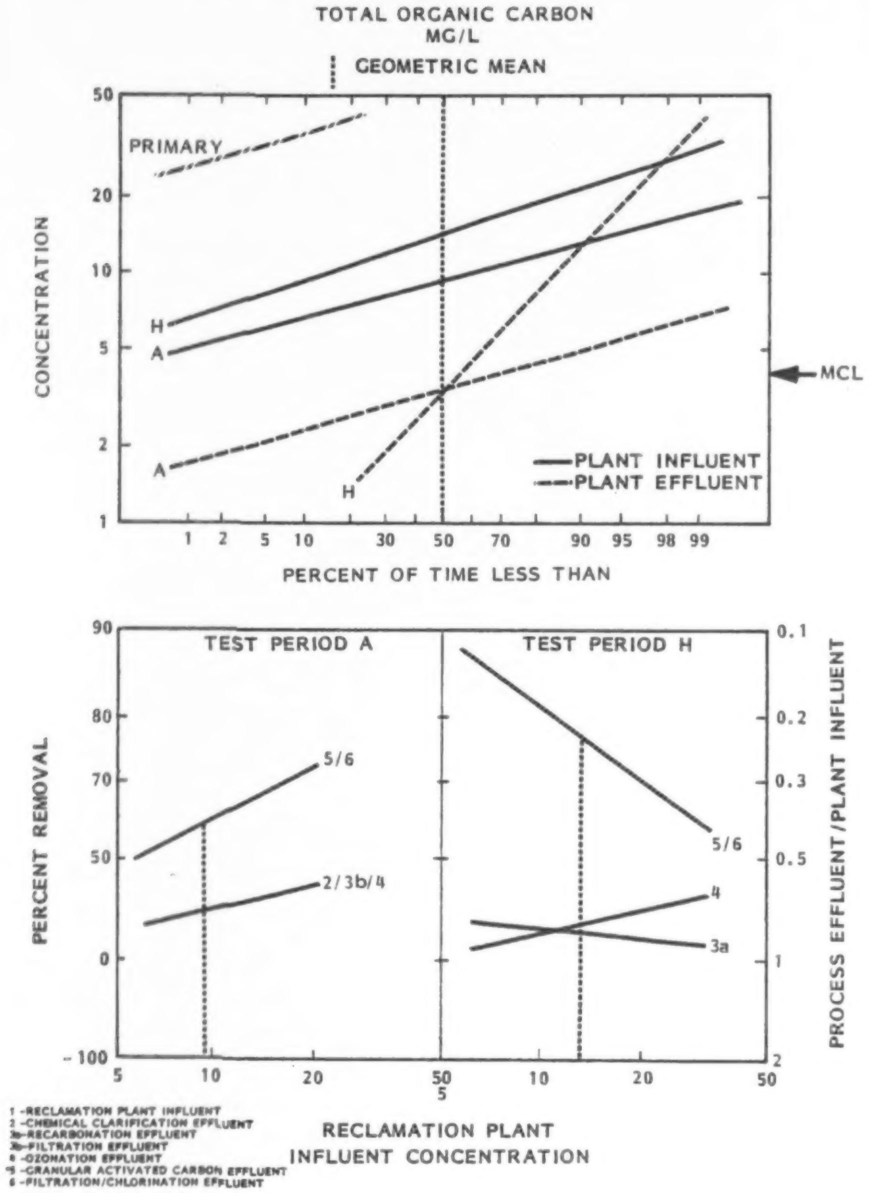


Figure 19 Data Distribution & Process Removal Characteristics

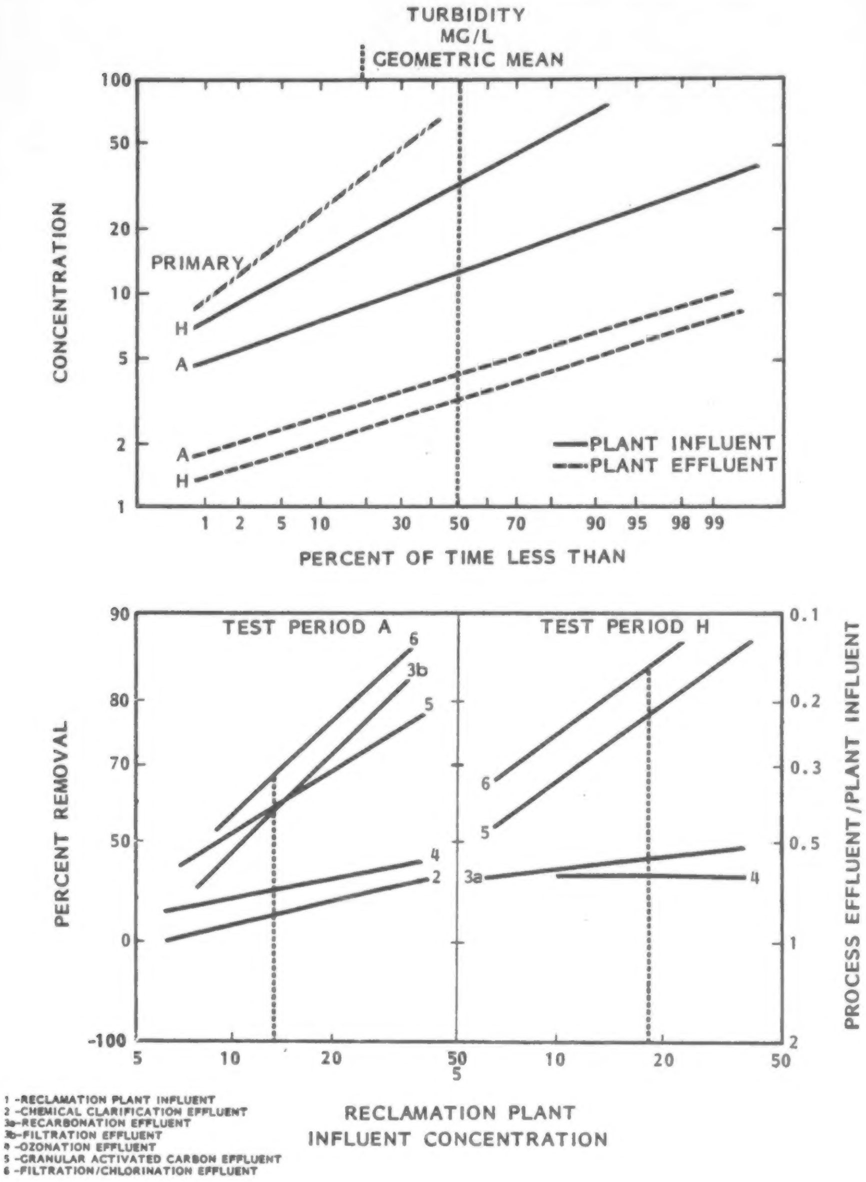


Figure 20 **Data Distribution & Process Removal Characteristics**

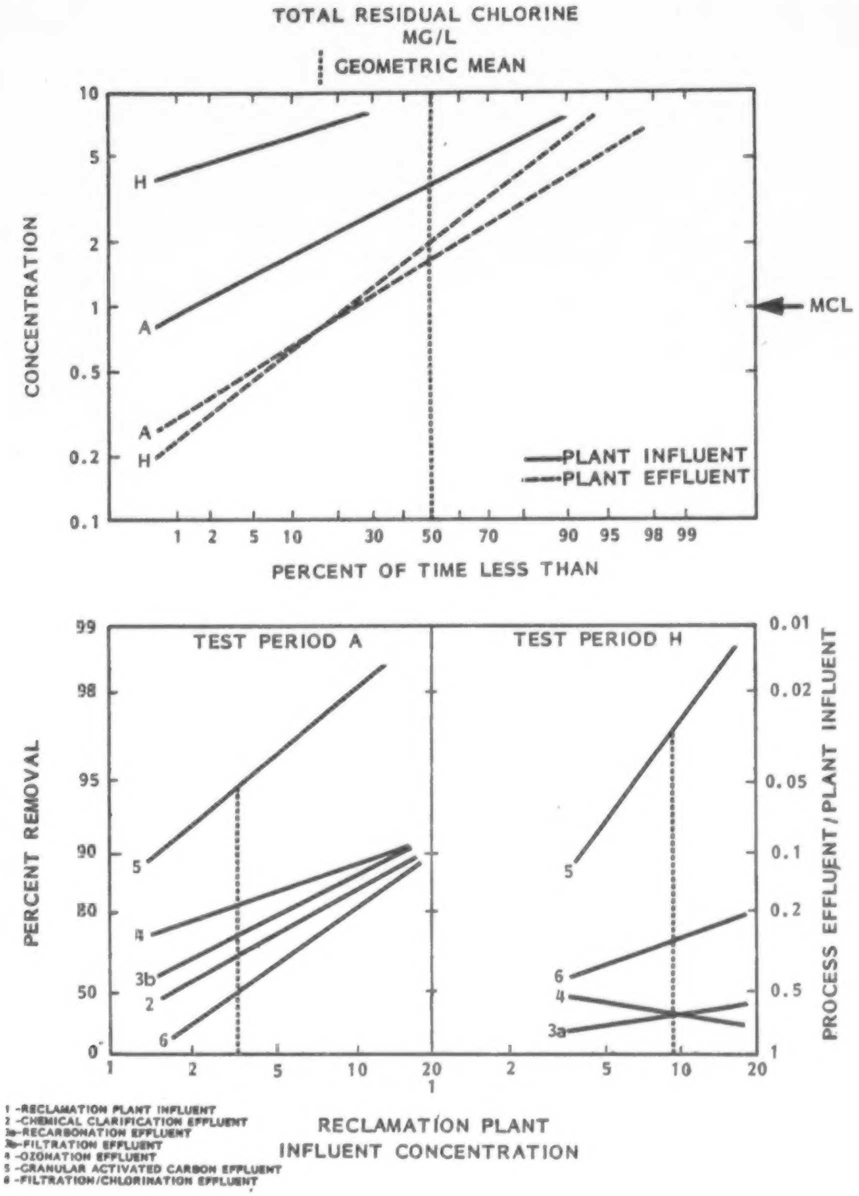


Figure 21 Data Distribution & Process Removal Characteristics

]

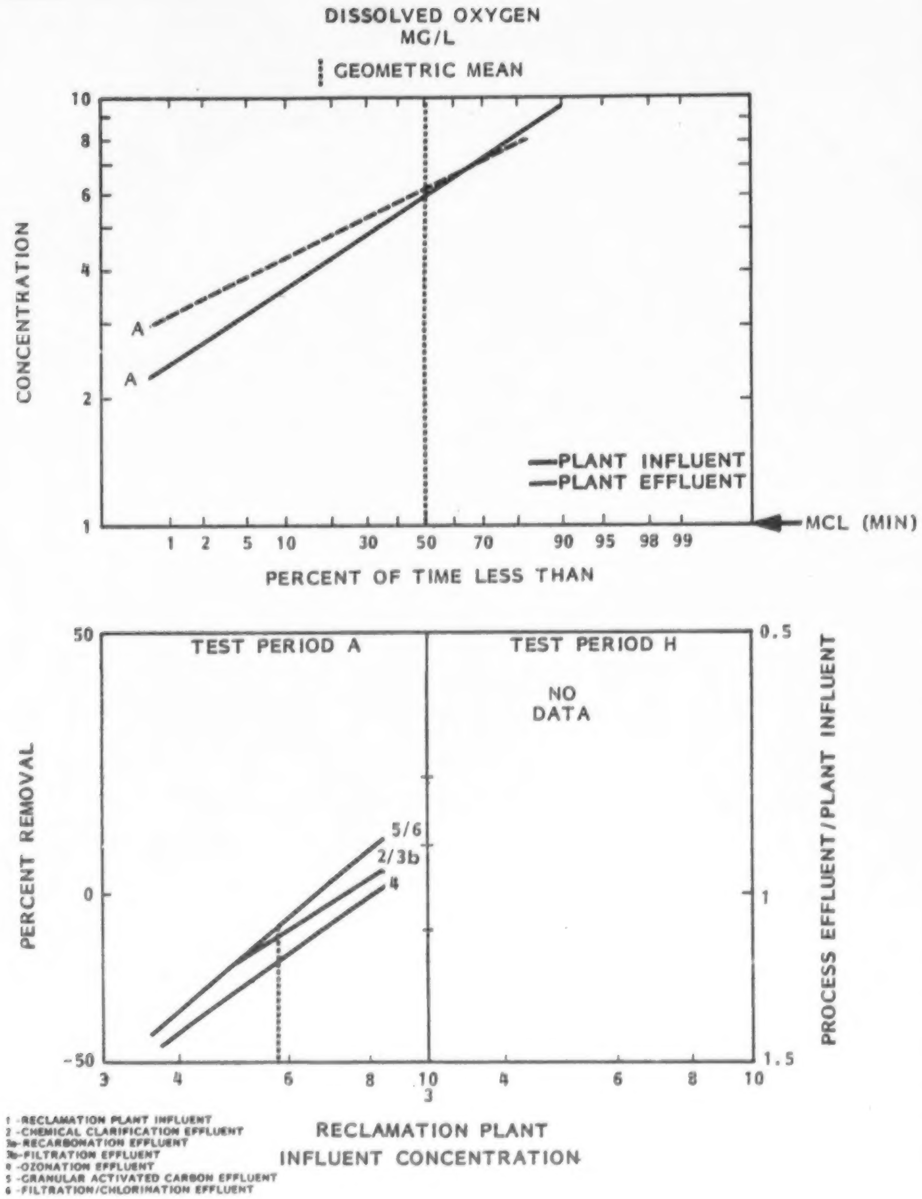


Figure 22 Data Distribution & Process Removal Characteristics

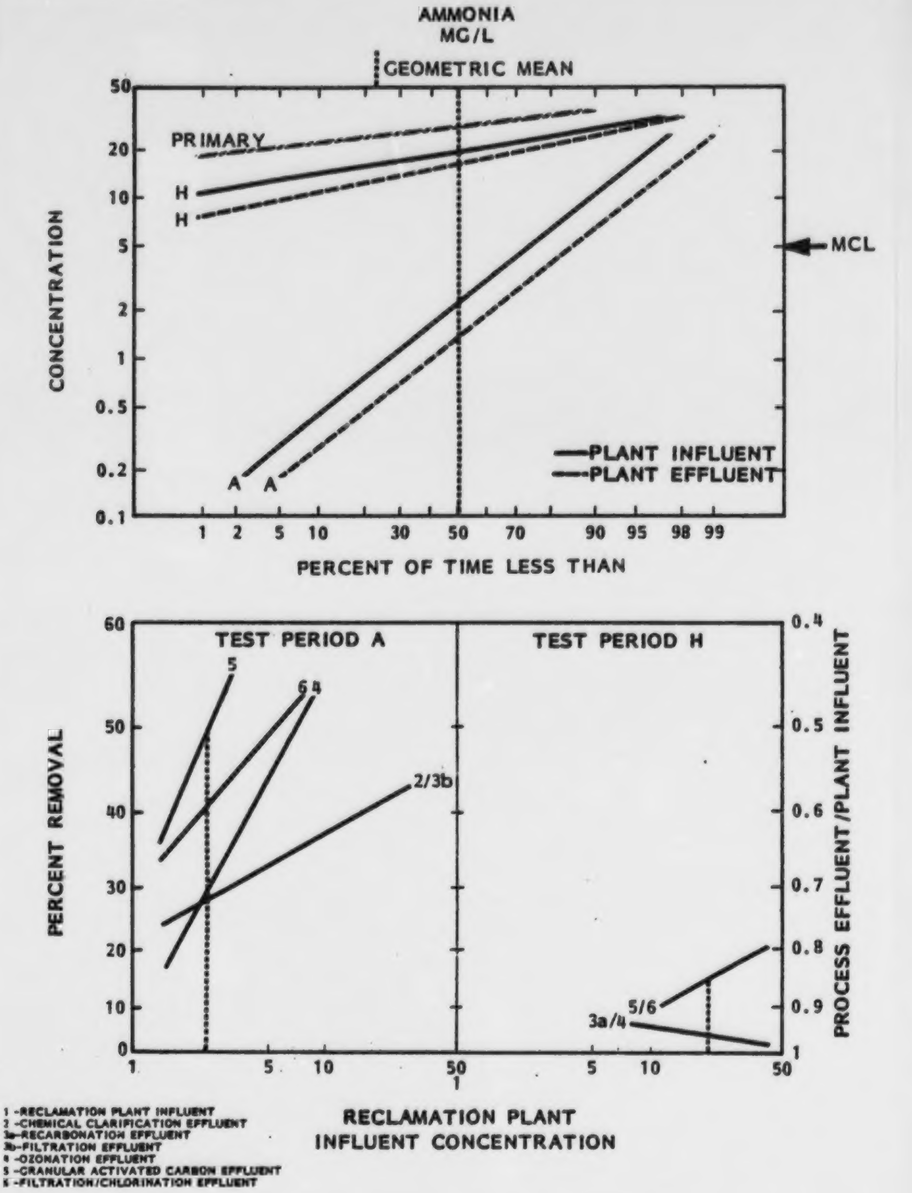


Figure 23 Data Distribution & Process Removal Characteristics

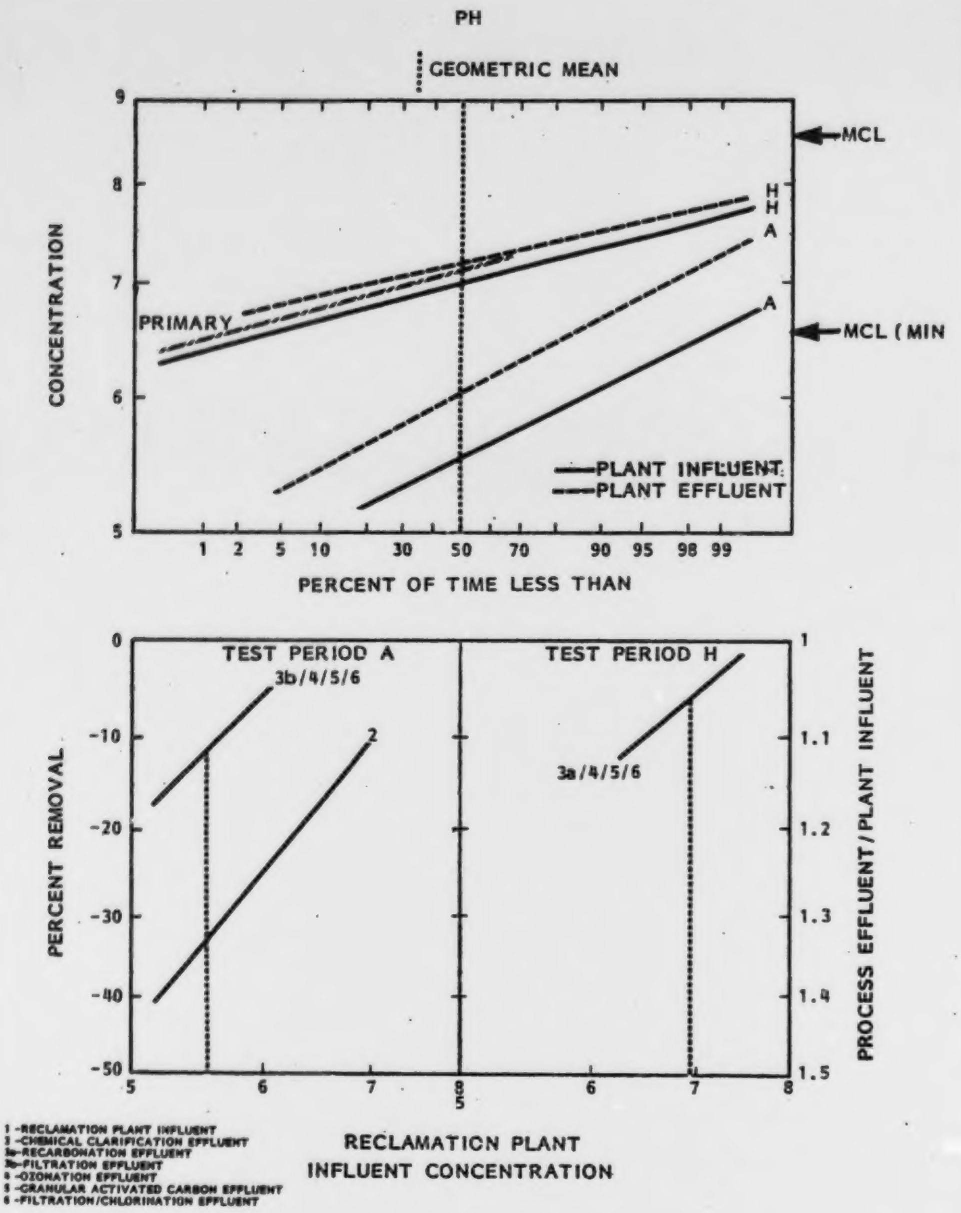


Figure 24 **Data Distribution & Process Removal Characteristics**

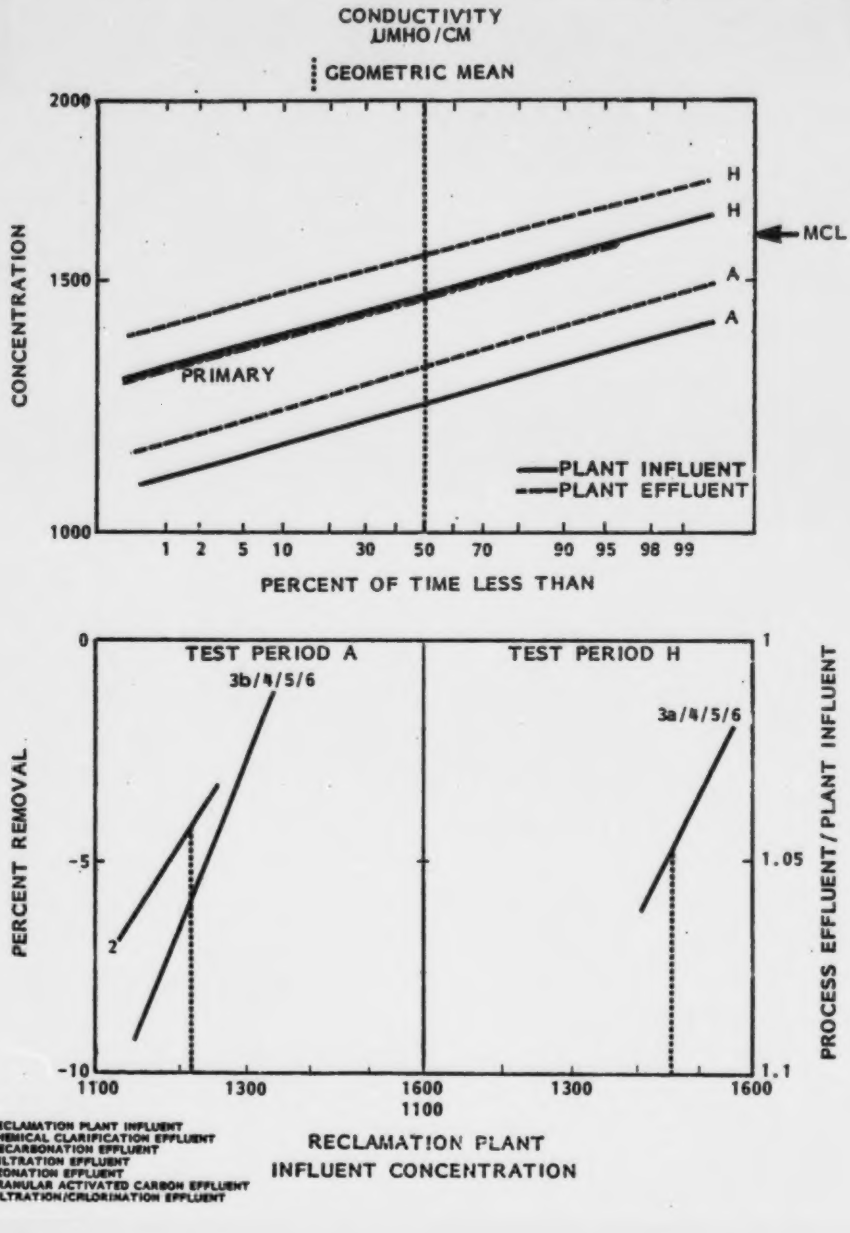


Figure 25 Data Distribution & Process Removal Characteristics

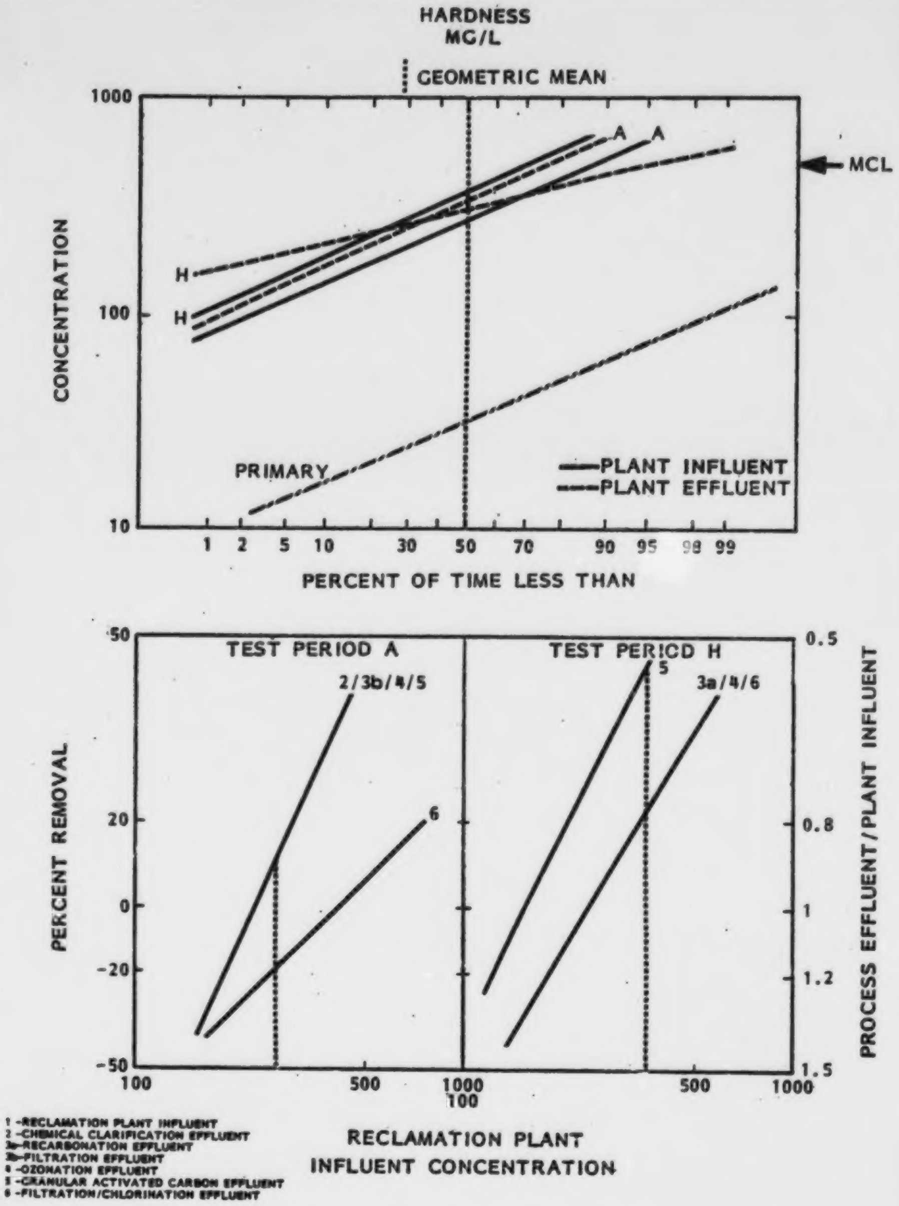


Figure 26 Data Distribution & Process Removal Characteristics

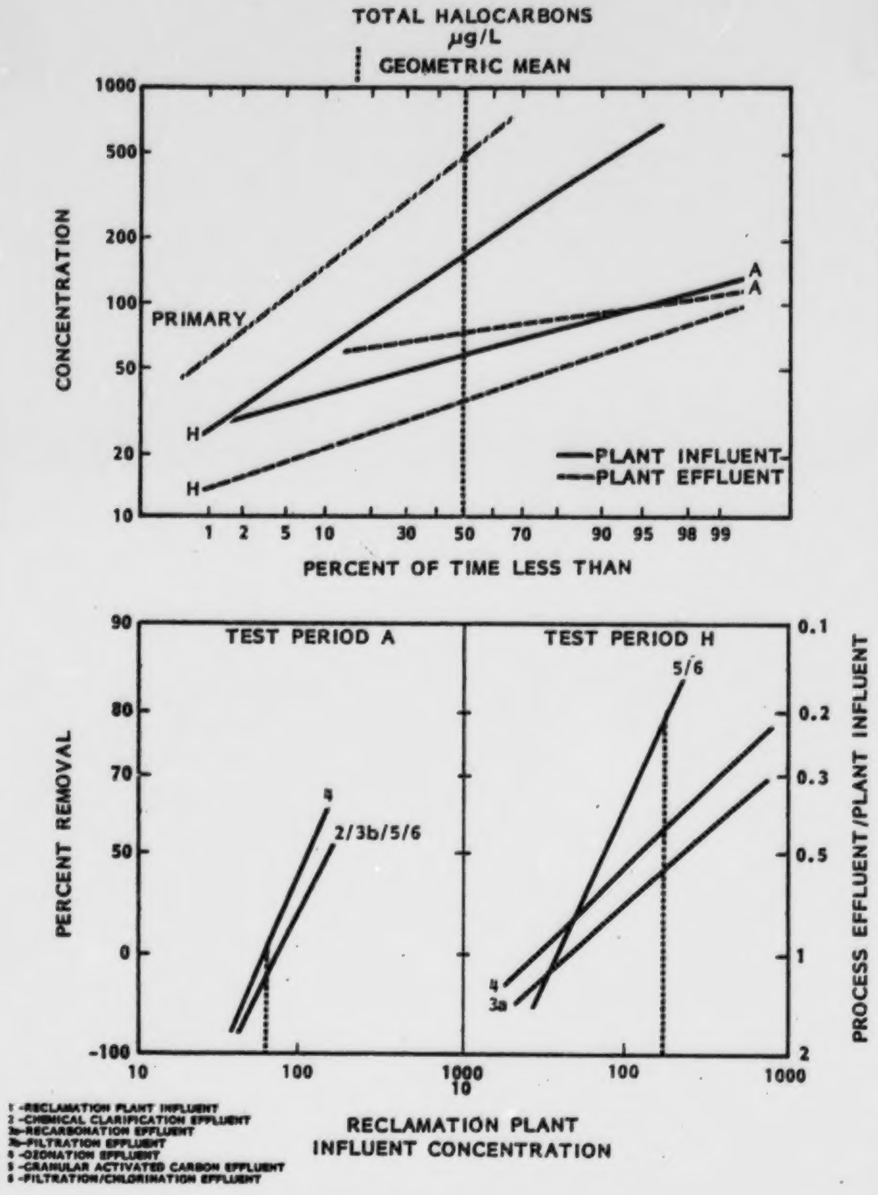


Figure 27 Data Distribution & Process Removal Characteristics

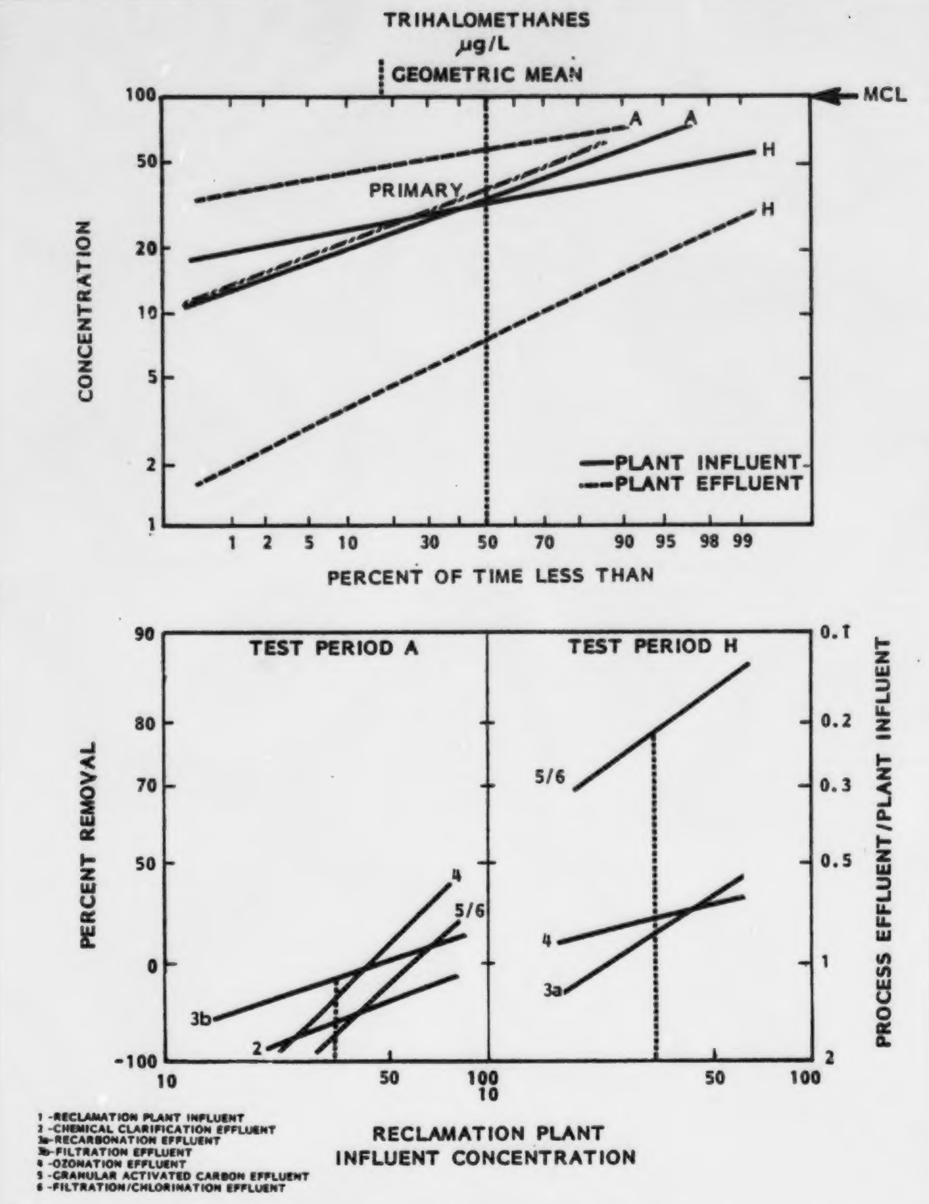


Figure 28 Data Distribution & Process Removal Characteristics

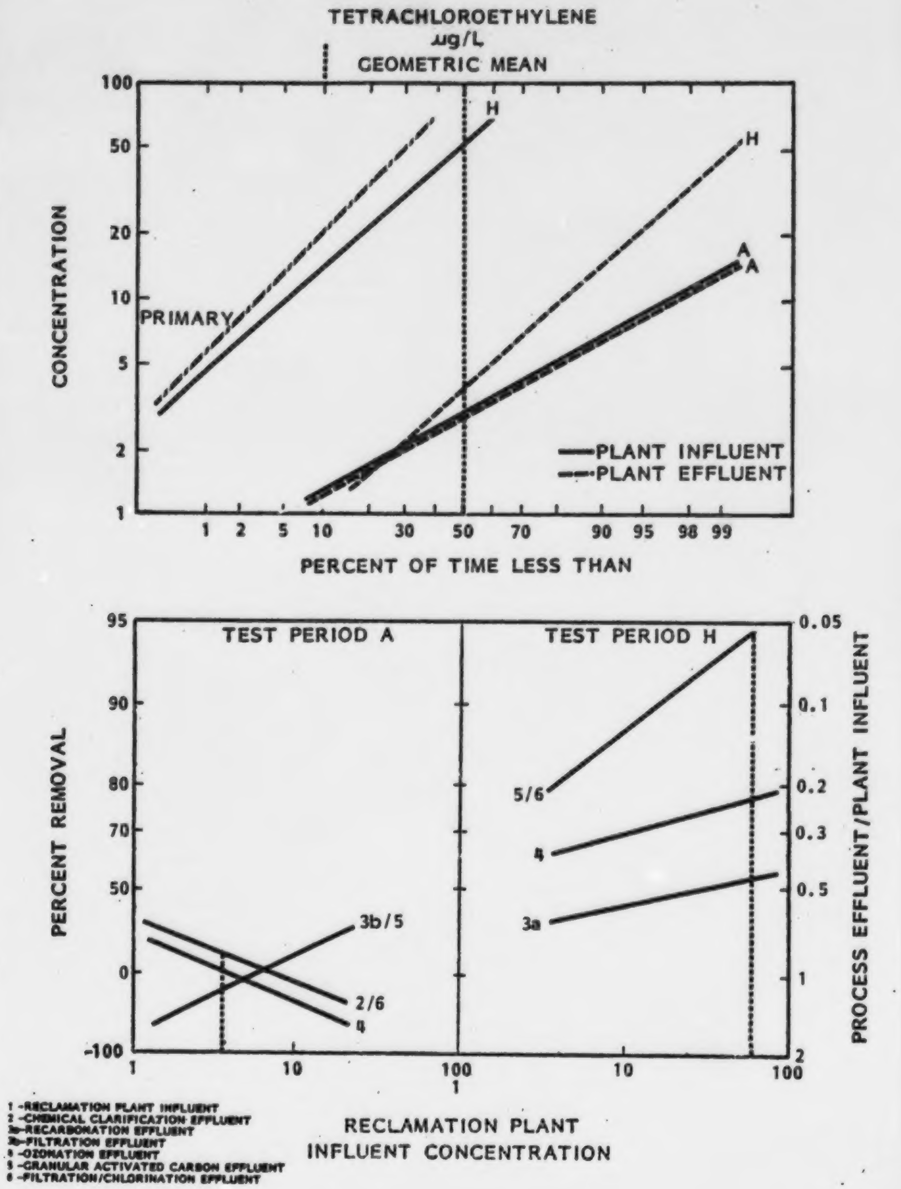


Figure 29 Data Distribution & Process Removal Characteristics

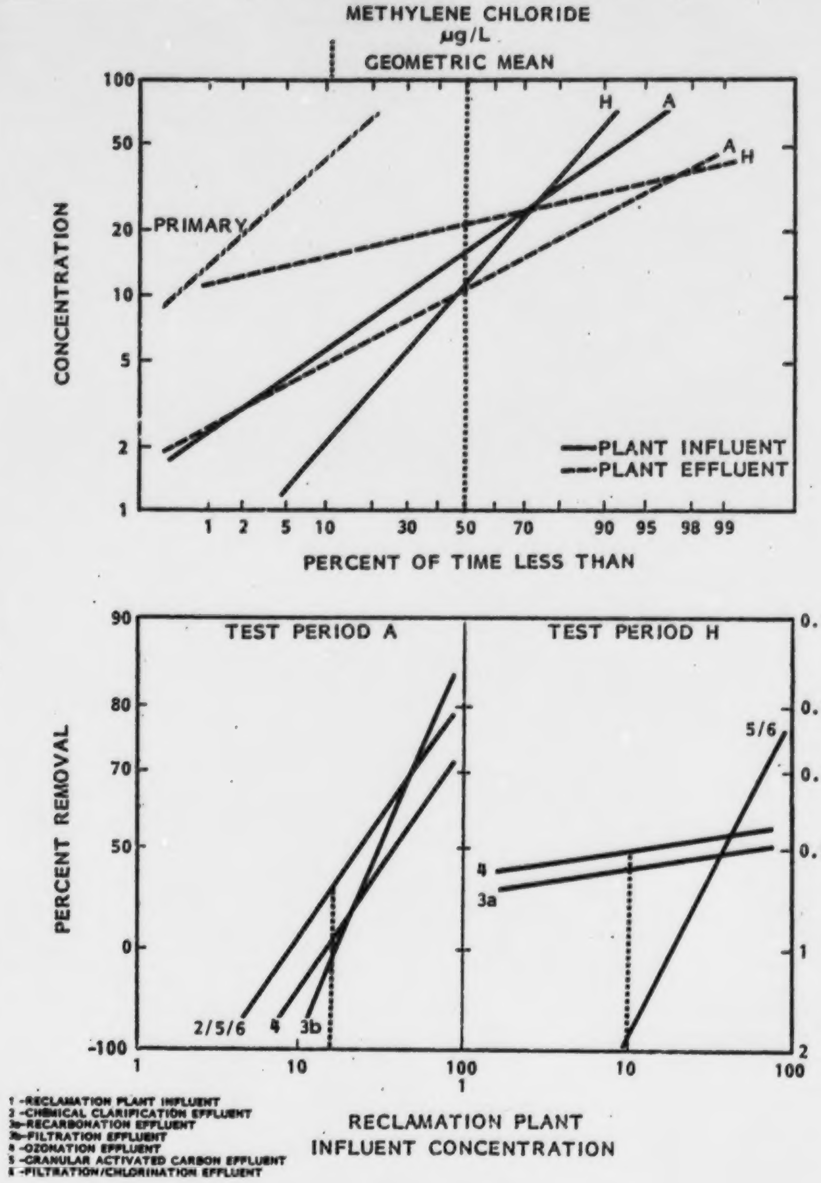


Figure 30 **Data Distribution & Process Removal Characteristics**

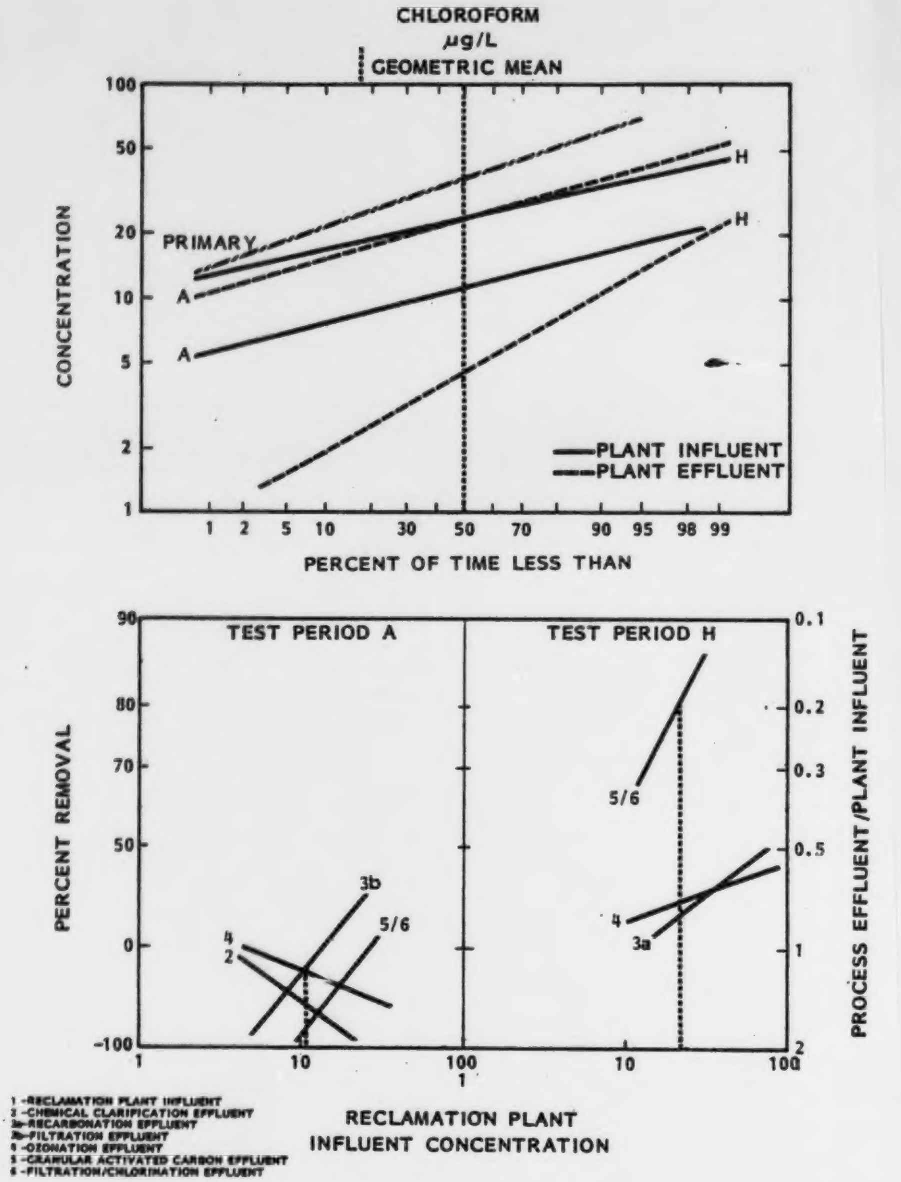


Figure 31 **Data Distribution & Process Removal Characteristics**

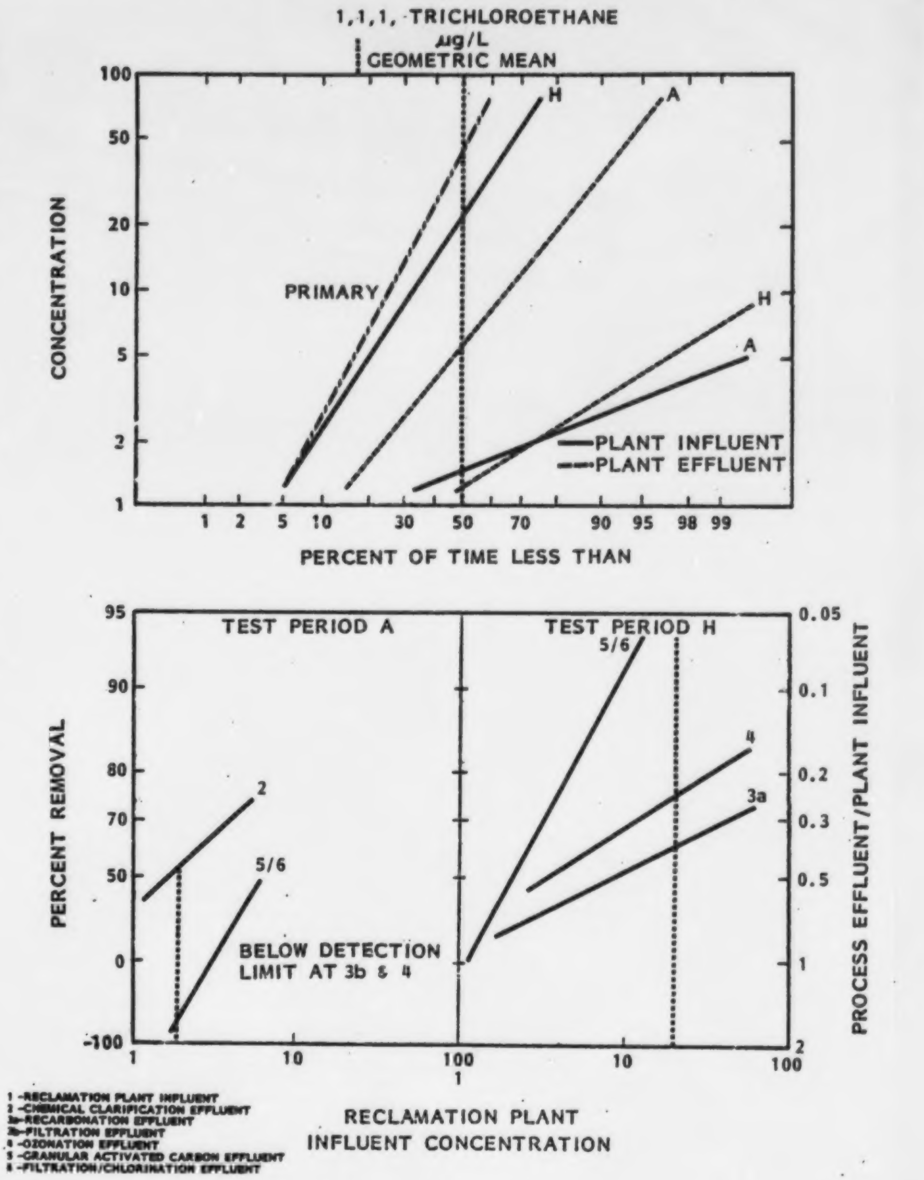


Figure 32 Data Distribution & Process Removal Characteristics

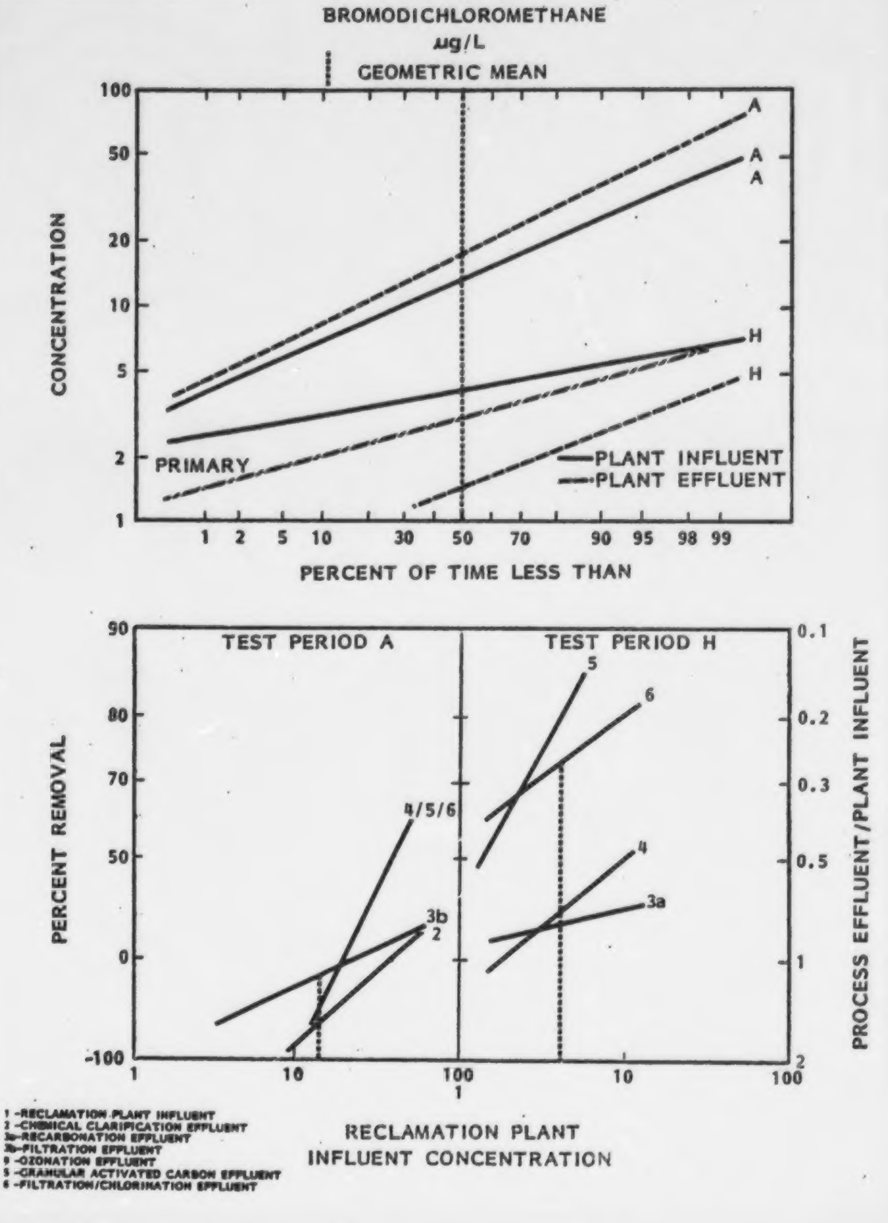


Figure 33 Data Distribution & Process Removal Characteristics

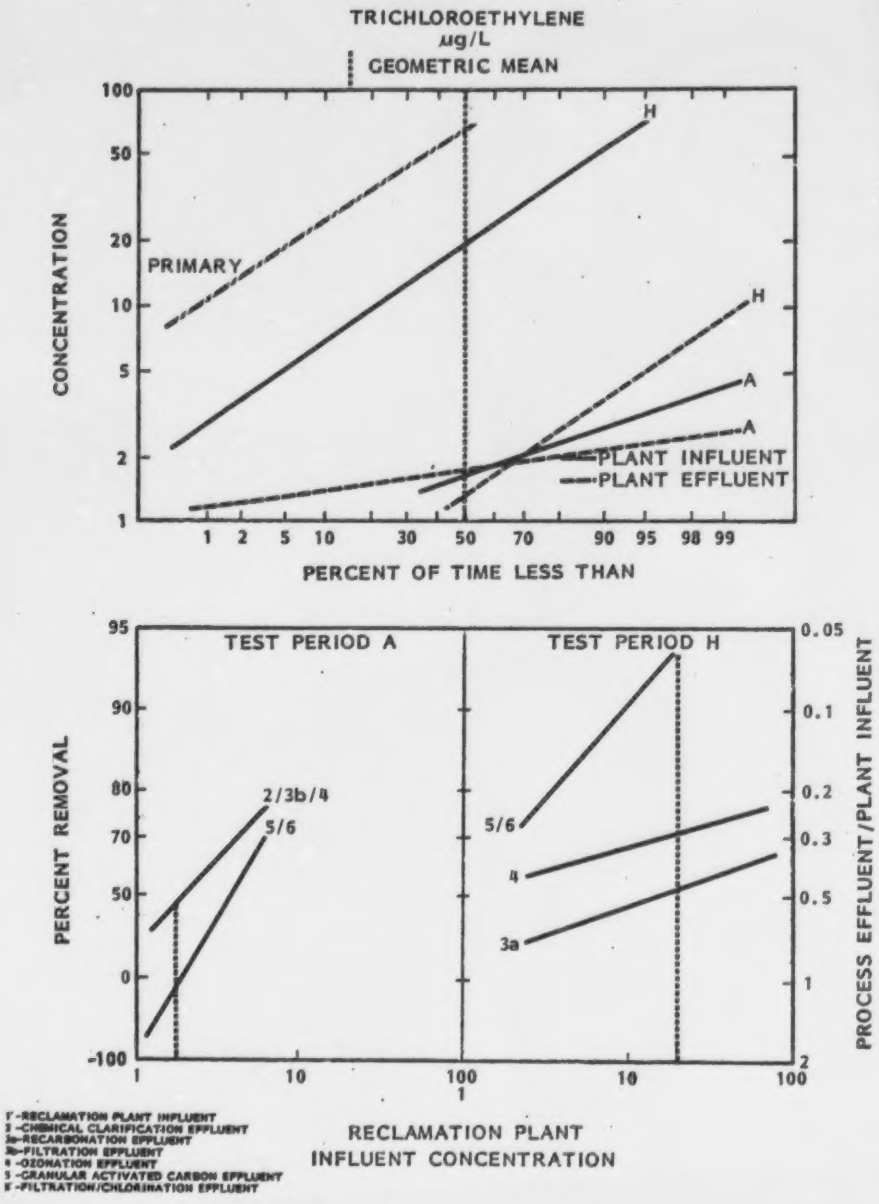


Figure 34 Data Distribution & Process Removal Characteristics

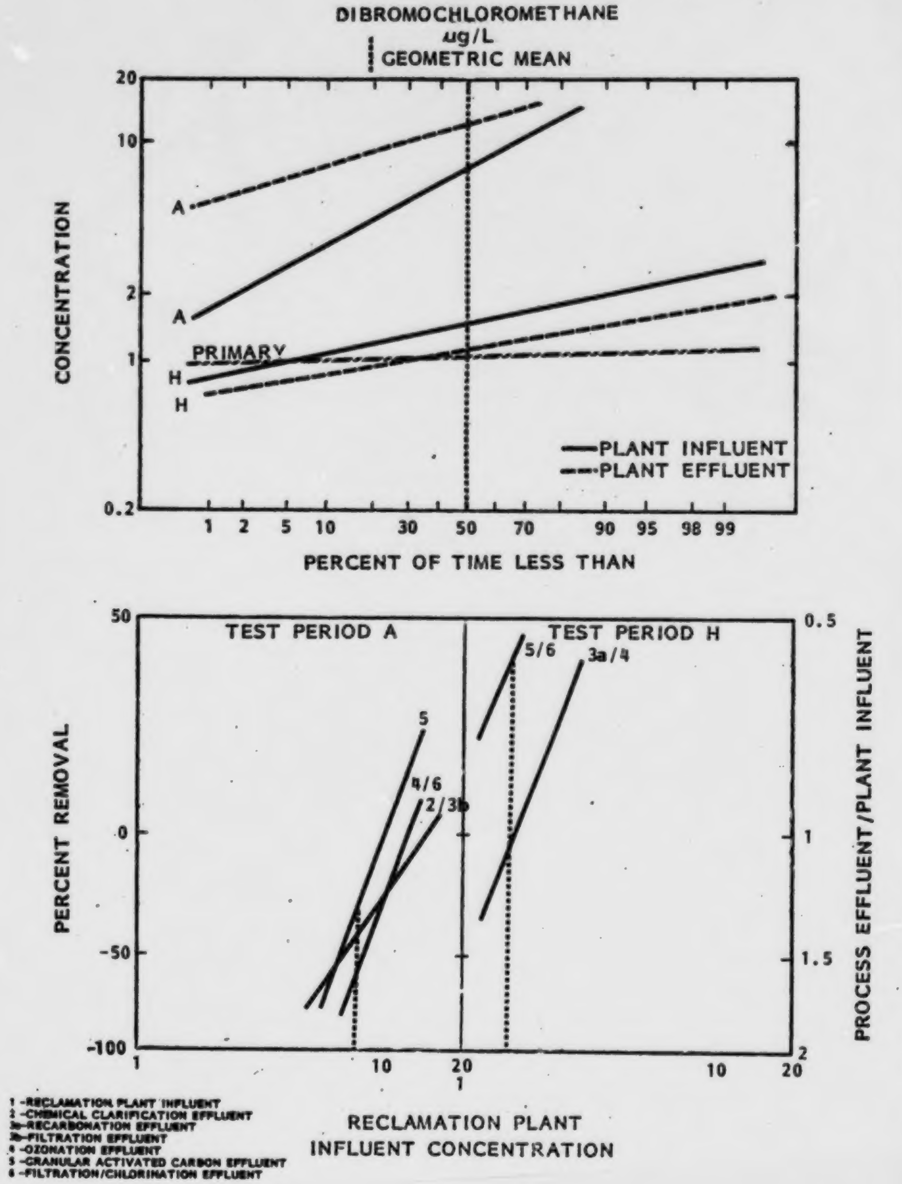


Figure 35 Data Distribution & Process Removal Characteristics

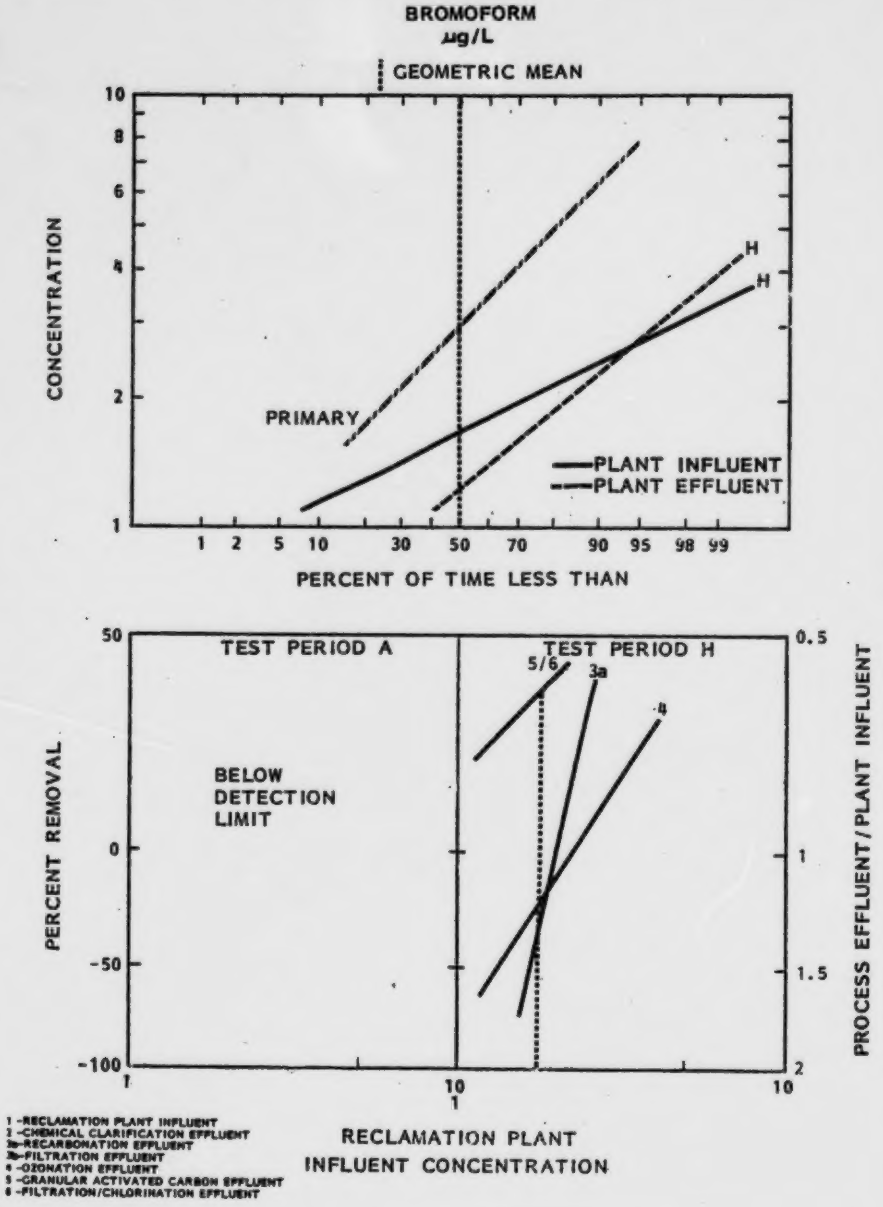


Figure 36 Data Distribution & Process Removal Characteristics

results of measurements made on primary effluent during the H test period, thus providing a graphic illustration of total treatment results beginning with settled raw wastewater through secondary treatment and, finally, through tertiary treatment. Additionally, comparison of the reclamation plant influent data for the two test periods shows the differences in performance of the secondary processes in each of the test periods.

The data displayed in the bottom graphs show process performance and were developed by a linear least-squares fit of each process output as a function of plant influent concentration based on a log-log model; i.e., log O = m log I + b. The results of this analysis are plotted in terms of percent removal and output/input for the influent concentration range indicated by the above lognormal distribution. The resulting curves allow the reader to follow a parameter through the plant (sampling points are consecutively numbered) and determine the cumulative contaminant removal as water progressed from process to process.

Figure 17, for example, shows in the upper graph the statistical distribution of the measured total biomass in the plant influent and effluent for test periods A and H. Total biomass in the primary effluent is also shown. The plotted curve illustrates how often the measured data were less than a particular value. Ideally there were an equal number of data points above and below the 50% point which is thus the mean of the data population. The variation of the data is reflected by the slope of the curve, where a horizontal line indicates that there was no variation. As a further illustration of the interpretation of these plots, the lower graphs in Figure 17 show the contribution of individual processes to contaminant removal. The period A results showed, for example, that most all the biomass in the influent was removed in chemical clarification, whereas the subsequent process, mixed media filtration, introduced additional biomass into the water stream, indicating that bacteria are growing and being continually eluted from the filter media.

The computerized data analysis from which figures 17 through 36 were constructed is included in Appendix A.

Table 15 shows the results of a test to determine whether process performance can be reliably described, as above, by simple statistical procedures; i.e., by the mean and the standard deviation. Values of chi square are shown for the lognormal data distribution model. If the data for a test period fit the assumed model, a value of 6 or less will be obtained in 19 of 20 trials (test periods), thus, the model may be rejected for values greater than 6 with at least 95% confidence.

Table 15 shows that these values ranged from near zero, indicating a near perfect fit of the data to the model, to 66, indicating an extremely poor fit. Over half (57 percent) of the measurements had chi square values of 6 or less. The parameters which most consistently showed normality were: methylene chloride, total halocarbons, viable biomass, conductivity, hardness, trihalomethanes, chloroform and pH. Total biomass, ammonia and TOC showed a pronounced change in normality between the two test periods.

TABLE 15

CHI SQUARES
OF PROCESS EFFLUENTS
FOR TWO TEST PERIODS

——— Period A ------- Period H

PROCESS		PRIMARY	SECONDARY	CHEM CLAR	CHEM CLAR/RECARB	RECARB/FILT	FILT/OZON	OZON	GAC	FILT/CHLOR
TOTAL BIOMASS	Period A		12	1		4		1	6	6
	Period H	23	2		7		24		9	24
VIABLE BIOMASS	Period A		33	5		6		3	1	6
	Period H	9	4		3		4		14	3
TOTAL RESIDUAL CHLORINE	Period A		6	1		7		2	81	12
	Period H		10		15		2		35	17
TURBIDITY	Period A		6	9		20		8	22	6
	Period H	50	2		29		20		9	3
DISSOLVED OXYGEN	Period A		38	8		8		4	11	19
	Period H									
TOTAL ORGANIC CARBON	Period A		11	13		14		15	1	9
	Period H	12	6		3		2		1	1
AMMONIA	Period A		12	9		9		16	19	24
	Period H	3	7		4		8		10	4
NITRATE / NITRITE	Period A									
	Period H									
pH	Period A		14	0		19		6	7	6
	Period H	6	5		4		7		5	4
CONDUCTIVITY	Period A		2	12		3		4	6	11
	Period H	2	6		8		4		3	6
HARDNESS	Period A		12	1		5		3	4	12
	Period H	1	3		0		3		2	7
SODIUM	Period A		3	4		4		7	1	8
	Period H									

TABLE 15 (Continued)

CHI SQUARES
OF PROCESS EFFLUENTS
FOR TWO TEST PERIODS

——— Period A ------- Period H

PROCESS		PRIMARY	SECONDARY	CHEM CLAR	CHEM CLAR/RECARB	RECARB/FILT	FILT/OZON	OZON	GAC	FILT/CHLOR
TETRACHLOROETHYLENE	Period A		8	27		2		10	5	6
	Period H	9	13		9		5		1	4
METHYLENE CHLORIDE	Period A		1	3		4		5	1	1
	Period H	2	3		3		1		4	2
1,2 - DICHLOROETHYLENE										
CHLOROFORM	Period A		8	1		6		8	7	3
	Period H	3	7		4		3		5	6
1,1,1 - TRICHLOROETHANE	Period A		25	8		24		56	15	16
	Period H	7	12		8		9		8	12
BROMODICHLOROMETHANE	Period A		9	6		1		4	3	17
	Period H	5	13		5		1		11	11
TRICHLOROETHYLENE	Period A		6	3		4		39	2	2
	Period H	7	4		2		12		15	30
DIBROMOCHLOROMETHANE	Period A		7	1		1		0	5	4
	Period H	21	7		6		2		66	34
BROMOFORM	Period H	2	2		30		4		3	4
TRIHALOMETHANES	Period A		9	8		1		0	5	3
	Period H	2	4		5		0		8	8
TOTAL HALOCARBONS	Period A		3	1		2		2	0	2
	Period H	3	7		4		6		2	9

It is proposed that the chi square value may reflect process stability; i.e., a high value preceded by a low value in the water treatment process train indicates that this process is susceptible to random and unexplained upsets. On the other hand, a low value preceded by a high value shows that the process is tolerant to influent upsets. Table 16 shows the number of parameters which had a significant change between the influent and effluent of processes. Chemical clarification followed closely by ozonation generally reflected a greater stabilizing effect while GAC seemed to have the greatest tendency for unexplained upsets.

TABLE 16

SIGNIFICANT CHANGES IN NORMAL DISTRIBUTION ACROSS PROCESSES

NUMBER OF PARAMETERS

	MORE NORMALLY DISTRIBUTED		LESS NORMALLY DISTRIBUTED	
	PHYSICAL/ CHEMICAL/ BIOLOGICAL SENSORS	GC	PHYSICAL/ CHEMICAL/ BIOLOGICAL SENSORS	GC
SECONDARY (PERIOD H)	4	1	1	3
CHEM CLAR/RECARB (PERIOD A)	5	2	1	0
CHEM CLAR/RECARB (PERIOD H)	1	4	3	1
RECARB/FILT (PERIOD A)	1	3	2	0
FILT/OZON (PERIOD H)	2	5	3	1
OZON	3	0	1	2
GAC (PERIOD A)	2	3	2	2
(PERIOD H)	0	2	2	3
FILT/CHLOR (PERIOD A)	2	1	5	1
(PERIOD H)	3	0	1	1

A consistently high chi square value may indicate that this particular water constituent or its sensor is inherently unstable. Only one measurement, trichloroethane, failed to show any lognormal distribution characteristics. On the other hand, if the chi square values were always low, say less than 1, the data may be "too good" and the responsiveness of the sensor might be suspect. Such consistently low values did not occur.

The following summarizes significant plant characteristics reflected by the data:

1. Influent Processing: The change in secondary treatment from activated sludge to fixed-film reactor/nitrification/dual-media filtration resulted in a significant reduction in reclamation plant loading for many contaminants.

2. Chemical Clarification:

    a. When operating at pH 11, essentially all the biomass is removed in the sludge and/or by cell lysis (disintegration at high pH). Biomass removal was less effective at the lower pH of 9.5 in period H where about 60% was removed.

    b. The turbidity measurement indicates that only about 25% of the suspended solids removed in the plant are removed by chemical clarification. In light of the biomass data, which indicate that a much larger portion of the suspended solids is removed in the clarifier, this small decrease in turbidity is attributed to floc carryover. Experience with fouling of downstream equipment by calcium carbonate deposits supports this interpretation.

    c. More TOC was removed; i.e., 3 versus 1.5 mg/l, when operating at the higher pH of period A (with aeration at pH 11, TOC removal increased to 5.5 mg/l during period G. The aerators were not operational during periods A and H).

    d. The concentration of the trihalomethanes is increased. This is probably due to the additional time that the chlorine is in contact with organics in the clarifier. This allows more chlorinated organic formation time.

    e. Ionic activity associated with lime treatment increases the conductivity. This suggests the possibility of controlling lime dosage using a conductivity sensor rather than pH sensor for operational reliability reasons; however, the durability of the conductivity probe in this environment has not been tested. The pH control currently used has been a consistent problem because of pH probe fouling in the high solids environment.

    f. An apparent pH anomaly was noted during period A. While the pH was controlled at 11 in the flash mixer, the measured value in the aerator sump tank just ahead of recarbonation was approximately 7. In previous test periods these two pH values have been nearly the same. The noted difference remains unexplained.

3. Ozonation:

   a. Ozonation results in a reduction in few of the measured parameters. (Presented here are the complete data collected during the test period. There were times during this period when the ozonator was not operating because of equipment failure. These periods are known, and an analysis could be performed to quantify the effect of ozonation by comparing ozonator operating data with ozonator nonoperating data. Because of time constraints, that analysis has not been done.)

   b. The increase in turbidity after ozonation appears to be an anomaly. This increase may result from entrained gases in the effluent sample. If so, they are very fine particles since they are not visible to the naked eye.

      It may be assumed that turbidity is not a reliable measure of the presence of suspended solids wherever entrained gases are introduced into the process stream. Sample points 2, 3b, 5, and 6 may thus be the only reliable points for measuring suspended solids by turbidity since gases may essentially be removed in the preceding process; i.e., clarification or filtration.

      If the ozonation effluent data are ignored, Figure 20 shows that much of the work of removing particulate matter, at least that which reflects light at 25 degrees, is done in the first filtration and not in the GAC as the data may seem to indicate. The plant's experience with persistent flocculant carryover from the clarifier with the accompanying calcium carbonate deposits on downstream equipment may support this interpretation of the data; e.g., there is no significant decrease in turbidity (suspended solids) before the initial filtration and the decrease in organic material (TOC and Biomass) in the chemical clarification is offset by an increase in calcium carbonate precipitant.

4. Mixed Media Filtration:

   a. Biological growth in the first filtration step results in an increase in biomass in downstream processes.

   b. The first filtration step provides the largest portion of the plant's turbidity removal. As discussed previously, this removal is largely floc carryover from chemical clarification.

   c. The addition of dual-media filtration in the secondary plant (period A) reduced the amount of solids in the reclamation influent and thus substantially increased the time periods between backwashes in the reclamation plant filters.

5. Granular Activated Carbon:

   a. A reduced level of many contaminants is characteristic of water processed by GAC, when its useful life is not exceeded. The virgin carbon used during period H resulted in a pronounced reduction in most organic materials. The exhausted carbon in the system during period A was saturated resulting in an increased rather than a decreased concentration for many of the measured trace organics.

b. All halocarbons are reduced in new GAC except methylene chloride, which is produced. In contrast, methylene chloride was removed by exhausted carbon during period A.

c. Most halocarbon concentrations were increased by GAC processing in period A because the carbon had been previously saturated at levels higher than the period A influent levels.

d. It is common to find biomass elution from GAC especially under favorable growth conditions; i.e., high dissolved oxygen, pH < 11, no ozone. Some growth was apparent during period H. Promoting biological growth in the GAC may extend its useful life (reference 4).

e. Most of the plant's ammonia removal occurs in the GAC probably by biological activity; i.e., by nitrification.

f. Mean TOC removal varied from 7.7 mg/l (O/I of 0.29) for new carbon in period H to 2.6 mg/l (O/I of 0.60) for exhausted carbon in period A. The TOC removal in period A is attributed to biological activity. In the adsorption operating mode, new GAC may be more accurately characterized as a constant TOC quantity removal process rather than as a percentage removal process (note the negative slope in Figure 19, period H, sample source 5). A different performance characteristic is obtained in the biological mode of period A.

g. Stanford University's Civil Engineering Department has conducted a test program to characterize activated carbon performance with operating age (reference 5). Composite samples were continuously collected for a period of 7 months (test period C) with the SCVWD-WRF/PA operating with three parallel carbon columns: The first containing virgin carbon, the second containing regenerated carbon, and the third containing exhausted carbon. Composite samples of the influent and the effluent of each column were periodically analyzed (usually once a week) for various organic compounds to determine the change in carbon removal performance with time. These data are presented in Appendix B.

   Included with the Stanford data in Appendix B are comparable WMS measurements made during the same time period. However, the WMS data were taken at a point after mixing of the effluent of the three columns. Thus, an average of the Stanford effluent data was computed to provide a data comparison which should be valid assuming equal flow through each of the three columns and good mixing ahead of the sampling point.

   A least-squares fit of the Stanford data for two of the measurements, TOC and chloroform, is shown in Figure 37, where performance is plotted as a function of age.

LEAST SQUARES FIT (DATA FROM APPENDIX B)

TOC

$$\left.\begin{aligned} O/I &= 0.123 + \frac{BV}{8700} \\ &= 0.123 + \frac{D}{204} \end{aligned}\right\} \quad r = 0.96,\ T = 8.5\ \text{MG/L}$$

CHLOROFORM

$$\left.\begin{aligned} O/I &= \log^{-1}\left[1.87 \log (BV) - 6.58\right] \\ &= \log^{-1}\left[1.87 \log D - 3.53\right] \end{aligned}\right\} \quad r = 0.92,\ T = 13.8\ \mu\text{G/L}$$

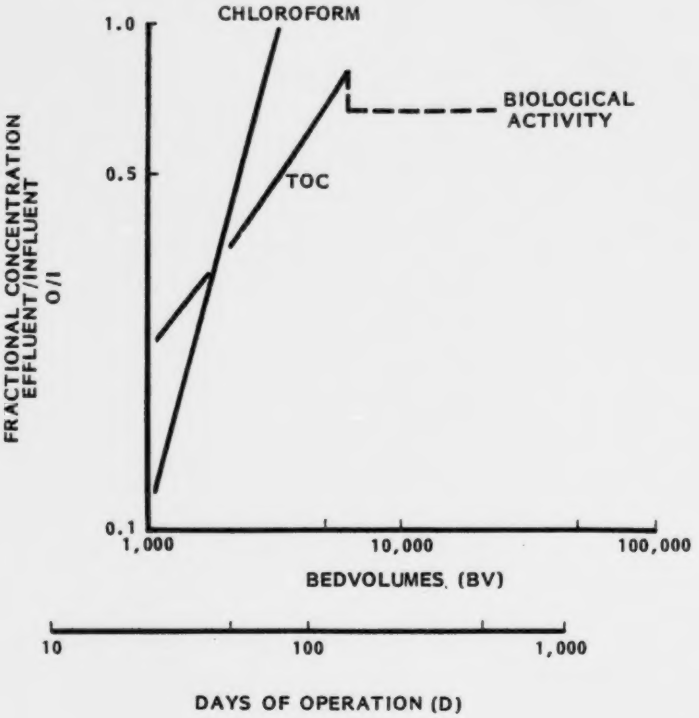


Figure 37 Time History of Granular Activated Carbon Performance

The data for chloroform indicate an effective operating life of 77 days with an adsorption capacity of 0.066 mg/gm carbon at 13.8 g/l. This value is consistent with previous test results with virgin carbon (reference 4). As indicated by the data in Appendix B, the GAC performance for chloroform is typical of the other volatile organics.

The Stanford data for TOC indicate an effective operating life approaching 179 days indicating an adsorption capacity of 63.2 mg TOC/gm carbon at 8.5 mg/l. However, at about 130 days, a discontinuity in the data indicates that action of biological growth on the carbon reached an equilibrium for the remainder of the test period with a TOC removal of about 5600 gms/day (0.28 mg TOC/gm carbon/day).

Better TOC removal by biological activity has been measured during previous test periods. During test periods F and G where the aerators were operating and the ozonator was not operating, over 50% better TOC removal performance in the GAC was indicated (reference 4). These results suggest that conditioning the influent to the GAC can have a significant influence on TOC removal performance and, thus, on carbon regeneration costs. These costs are discussed in a later paragraph.

Plant/Process Availability

Plant and process availability (percent of time the plant/process operates on demand) was monitored during the test period. The objective of operating the plant continuously for the 8-month (5832-hour) test period was met except for 69 hours when plant influent was unavailable, and when plant equipment failed. The operating time and downtime-for-repair periods for each of the processes are summarized in Table 17. Equipment failures experienced during the 8-month test period resulted in an estimated 20 days annually when the plant would be unable to deliver product; i.e., reclaimed water.

Included in this analysis is consideration of product storage capacity. Plant shutdowns of less than 8 hours were not recorded as plant downtime since reclaimed water could be delivered at the operating flow of 0.066 m^3/sec. for up to 8 hours from the 1893 m^3 effluent storage tank.

The individual processes did not have the capability to continue process operations when equipment failed because there was negligible intermediate storage. Therefore, the downtimes recorded for each of the processes are actual repair times. However, in many cases equipment failures did not result in plant shutdown because the capability to bypass nonoperating processes was afforded by plant design flexibility.

The problems necessitating process equipment repair are outlined in Appendix C. There were three predominant problems:

1. Calcium carbonate encrustations on equipment causing pump malfunctions and scale buildup on the inside walls of piping, thereby reducing flow capacity.

TABLE 17
AVAILABILITY OF
PALO ALTO RECLAMATION FACILITY
JULY 1, 1980 THROUGH FEBRUARY 28, 1981 [1]

	OPERATING TIME, HR.	DOWNTIME, HR.	AVAILABILITY, %	ESTIMATED YEARLY DOWNTIME, DAYS
CHEMICAL CLARIFICATION	4,993	654	88.4	43
RECARBONATION	4,825	91	98.1	7
OZONATION	4,160	1,217	77.4	83
MULTIMEDIA FILTRATION	5,324	0	100.0	0
CARBON SORPTION [2]	5,324	0	100.0	0
CHLORINATION	5,324	0	100.0	0
COMPUTER	5,324	81	98.5	6
PLANT (PRODUCT DELIVERY)	5,455	308	94.7	20

NOTE:

1. **THE PROBLEMS REPORTED WHICH RESULTED IN DOWNTIME MAY BE UNIQUE TO THE EQUIPMENT & SYSTEM DESIGN OF THIS PARTICULAR FACILITY.**

2. **CARBON REGENERATION FURNACE WAS NOT OPERATED DURING THE TEST PERIOD.**

2. Plumbing failures within the ozonator.

3. Carbon furnace equipment component failures. Carbon was regenerated from the unused tower during the test period. The operator efforts required to do this were quite intensive. After complete regeneration of this tower, it was decided to cease any further regeneration. This decision was based on labor requirements and the fact that Stanford University's research involved long-term sorption characteristics of activated carbon without regeneration.

   The increased labor was due primarily to carbon furnace failures which included jamming of 1) the dewatering screw, 2) the horizontal feed screw, 3) the carbon drop chute, 4) the outlet at the base of the carbon furnace as it enters the quench tank, and 5) the bottom of the spent carbon storage tank during carbon transfer. Also, the burner temperature control sensors malfunctioned quite frequently which resulted in improper temperatures within each hearth of the multiple hearth furnace. The operators spent considerable time unjamming the previously mentioned problem areas, and the operation required close attention during the regeneration process. Miscellaneous breakdowns included boiler breakdown, I.D. fan failures, and clogging at the outlet of the quench tank which added to the problems. This necessitated the discontinuance of further attempts to regenerate carbon.

Plant Reliability

Figure 38 illustrates the method of determining plant reliability. The data distribution curve, Figures 17 to 36, at the MCL establishes the probability (reliability) that plant effluent will not exceed the MCL.

Plant reliability (percent of operating time that the plant effluent was within given limits) is summarized in Table 1. Some of these limits are illustrative only in that they are not discharge limits on this particular plant but are potential limits should the plant effluent be used for potable or irrigation purposes.

Plant O&M Costs

The O&M costs of the plant during the 8-month test period are presented in Table 18. Extrapolation of these data gives a projected annual plant production cost of $311,400. Water production costs were $0.16 per 1000 liters.

The distribution of costs as determined from the totals shown in Table 18, including all categories, may be summarized as follows:

	Labor	Materials	Total
Operations	49.4%	25.5%	74.9%
Maintenance	22.5%	2.6%	25.1%
Total	71.9%	28.1%	100.0%

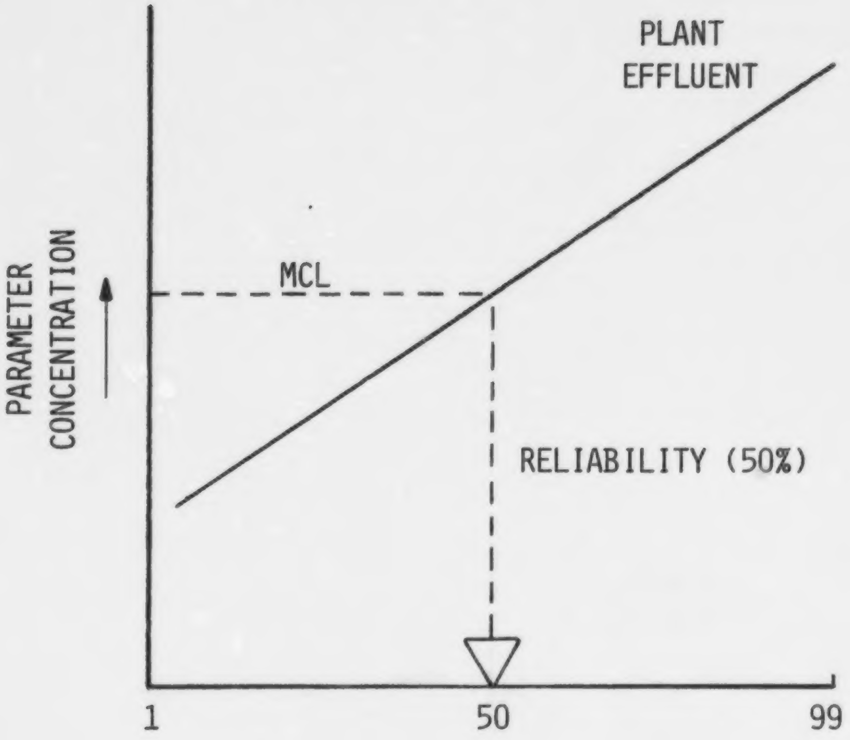


Figure 38 Determination of Reliability (Example)

TABLE 1

RELIABILITY OF PALO ALTO RECLAMATION FACILITY

	MAXIMUM CONCENTRATION LIMIT MCL	MINIMUM CONCENTRATION LIMIT MCL (MIN)	REFERENCE	RELIABILITY	
				PERIOD A	PERIOD H
CHEMICAL OXYGEN DEMAND	10 mg/l	-	9	65.0% [1]	57.8%
TRIHALOMETHANES	100 mg/l	-	10	>99.9%	>99.9%
TOTAL NITROGEN	5 mg/l	-	9	86.1% [2] (NH_3)	<0.0%
pH	8.5	6.5	9	18.7%	99.9%
DISSOLVED OXYGEN	-	1 MG/L	9	>99.9%	-
HARDNESS	500 mg/l	-	11	78.6%	97.3%
SODIUM	250 mg/l	-	12	>99.9%	-
TOTAL RESIDUAL CHLORINE		1 MG/L	9	76.2%	77.5%
CONDUCTIVITY	1600 umho/cm	-	13	>99.9%	70.9%
TURBIDITY	5 NTU		9	-	-

NOTES:

1. ASSUMES COD/TOC RATIO OF 2.5.
2. BASED ON AMMONIA OR NITRATE CONCENTRATION.

TABLE 18

OPERATIONS & MAINTENANCE COSTS OF
PALO ALTO RECLAMATION FACILITY
JULY 1, 1980 THROUGH FEBRUARY 28, 1981

[1]

	OPERATIONS	MAINTENANCE	LAB	ADMINISTRATION & ENGINEERING	TOTALS
CHEMICAL CLARIFICATION					
LIME	$19,290	-	-	-	$32,890
LABOR	-	$13,600	-	-	
RECARBONATION					650
LABOR	-	650	-	-	
OZONATION					3,960
LABOR	-	3,960	-	-	
MULTIMEDIA FILTERS	-	-	-	-	-
CARBON ADSORPTION [2]	-	-	-	-	-
CHLORINATION					580
CHLORINE	580	-	-	-	
COMPUTER					13,770
LABOR	-	13,770	-	-	
GENERAL PLANT OPERATIONS [3]					155,740
ELECTRIC	30,650	-	-	-	
GAS	2,360	-	-	-	
MATERIALS & SUPPLIES	-	5,440	-	-	
LABOR	64,870	-	23,110	29,310	
TOTALS	$117,750	$37,420	$23,110	$29,310	$207,590

TOTAL WATER COST = \$0.16 PER M^3 (\$0.60 PER 1000 GAL.)

PROJECTED YEARLY O & M COST = $311,400

NOTES

1. LABOR COST OF $37/HR. FOR ENGINEERING; $27/HR. FOR ALL OTHERS. ◁
2. CARBON WAS NOT REGENERATED DURING THE TEST PERIOD.
3. INCLUDES PREVENTIVE MAINTENANCE AND MINOR MAINTENANCE REQUIRING LESS THAN FOUR HOURS LABOR.

▷ THE COSTS REPORTED HERE MAY BE UNIQUE TO THE EQUIPMENT & SYSTEM DESIGN OF THIS PARTICULAR FACILITY. CARE MUST BE EXERCISED IN EXTRAPOLATING THESE COSTS TO OTHER SYSTEM DESIGNS OR DIFFERENT PLANT CAPACITIES.

The labor costs shown under the subheading General Plant Operations include preventative maintenance on all equipment contained within the reclamation facility. It also includes maintenance that require less than 4 hours of effort. Operator process monitoring, filter backwashing, plant rounds keeping, and miscellaneous water quality testing are included in this category. Plant operators', electricians', and mechanics' labor constitutes the majority of the cost in this category. This subheading is to cover those undefinable labor costs that could not be allocated specifically to a unit process.

These costs did not include carbon replacement/regeneration since exhausted carbon was used throughout the test period. If carbon had been regenerated, the costs could have increased significantly.

Figure 39 illustrates potential water cost based on a $0.227 per kilogram carbon regeneration cost and a TOC effluent upper limit of 4 mg/l. The figure shows the strong cost dependence on influent conditions and performance reliability. For example, the water production cost presented above ($0.16 per 1000 liters) would about double for plant influent conditions of test period A, if 99 percent reliability were achieved. For the lower quality influent of test period H, the production cost could have more than doubled.

It should be noted that a significant but unconfirmed assumption was made in developing Figure 39; i.e., the performance achieved by continuously regenerated carbon, based on average carbon age existing in the column, will be the same as that obtained when the column contains all carbon of the same age. This assumption allows the carbon performance of Figure 37 to be used in computing continuous regeneration rates. The linear decay in performance seems to substantiate the assumption; however, the resulting computed costs should be considered approximate until actual tests confirm the postulated performance.

The sudden tail-off of the cost curve for period A occurs at about 50% reliability below which steady-state biological growth on the carbon maintains performance without the necessity of carbon regeneration.

It is significant to note that if over 50% reliability is to be maintained, costs will be incurred which will significantly increase the cost of water production.

BASIS

1. COD LIMIT OF 10 mg/l. COD/TOC RATIO OF 2.5.
2. INFLUENT CONCENTRATIONS OF FIGURE 19 .
3. PERFORMANCE WITH CONTINUOUS CARBON REGENERATION IS THE SAME AS THAT SHOWN IN FIGURE 37 BASED ON AVERAGE CARBON AGE.
4. CARBON REGENERATION COST OF $0.227 PER KILOGRAM.

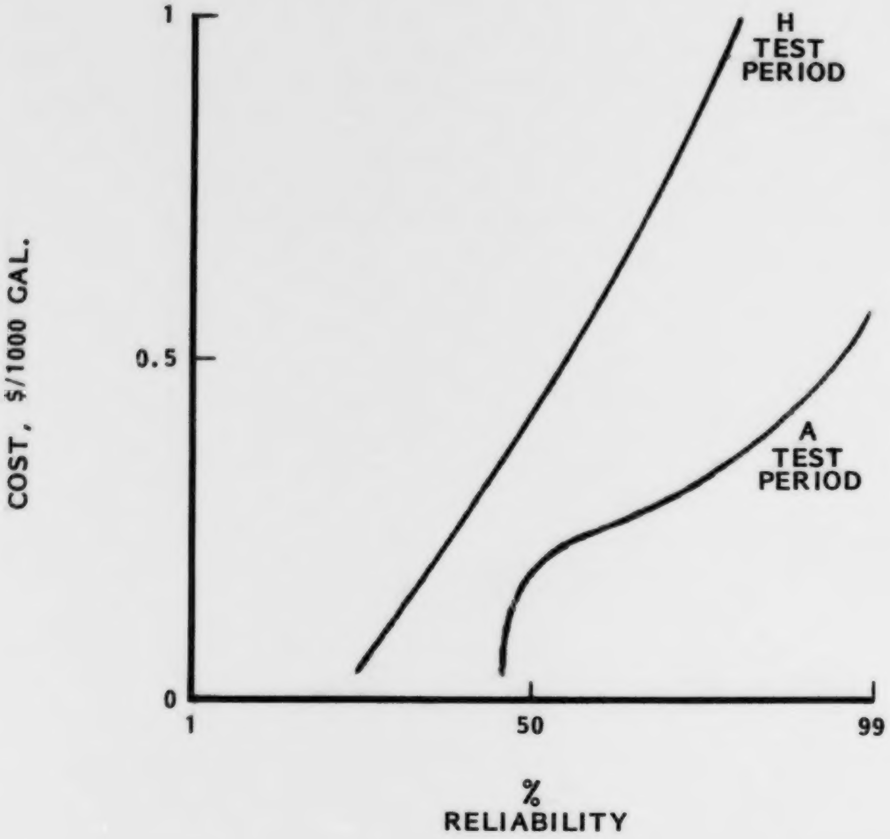


Figure 39 Relationship Between Cost & Reliability for Complying With COD Discharge Limit by Granular Activated Carbon Regeneration

SECTION 6

FUTURE APPLICATIONS

A primary responsibility of the Santa Clara Valley Water District is to insure an adequate quantity and quality of water supplies for Santa Clara County, California. The existing needs are met from local and imported supplies. Local supplies are from the natural yields of the County's three interconnected subbasins and the yields of the major tributary surface drainage areas into District reservoirs. Water is imported into Santa Clara County from the South Bay Aqueduct of the California State Water Project. In addition, water is imported through the City of San Francisco's Hetch-Hetchy Aqueduct by various cities in North Santa Clara Valley. Imported water is needed in Santa Clara County even during an average rainfall year, and a new importation supply from the Bureau of Reclamation San Felipe Division of the Central Valley Project is being constructed to fill this need.

The Santa Clara Valley Water District is committed to developing alternative supplies including reclaimed water. There are, however, barriers to reuse - principally economic and assurance of safety (i.e., water quality). The Palo Alto Reclamation Plant and the NASA WMS have been crucial projects for exploring these barriers.

Early in the Palo Alto Reclamation Project, the Santa Clara Valley Water District concluded that on-line water quality analysis would be essential to the successful marketing of high quality reclaimed water, and contacted NASA for their help and expertise in this area.

It was felt that even though there are wet chemistry analyses available for determination of water quality, these tests would be unacceptable because it often takes days before the results are obtained, long after the water would have been reused.

With the WMS, the effluent quality can be monitored on a real-time basis. If for any reason the effluent quality deteriorates, then the effluent can be diverted to waste. The WMS also was helpful in evaluating reclamation unit processes by monitoring quality improvement in each unit process. This permitted evaluation of the effectiveness of each treatment process and unit process economics. Results from the experiment indicate that such monitoring of treatment plant effluents on a continuous basis can better enable treatment plant operators to achieve optimal performance from each unit process.

The long term future applications of automated water quality monitoring appears bright but its immediate future is not well defined. Several factors need clarification, such as, the legal aspects of "product liability" of reclaimed water, and current EPA and DOH monitoring requirements for potable and wastewater. Since the demand for potable water is continuing to increase and the sources of pristine water are not increasing, it appears certain that wastewater will have to be reused. If water is to be reused, it is important that its quality be assured on a continuous basis. Automation is the only economically feasible (see cost comparison in Table 19) means of meeting such a need. The use of continuous monitoring data from the WMS as control functions for the treatment plant process control computer can result in a closed loop control of the wastewater reclamation plant resulting in reduced chemical and power usage in the various treatment processes. These benefits will be optimized by the use of closed loop control. Estimated costs of a comparable number of analyses by typical laboratory techniques are shown. These estimates are based on the results of a telephone survey conducted by the Santa Clara Valley Water District.

TABLE 19

ESTIMATED COSTS AND SAVINGS
FOR AUTOMATED INSTRUMENTATION

	LAB		WMS
CAPITAL COSTS, $			
SENSORS/SUPPORT EQUIPMENT	—	SAME	—
AUTOMATION (COMPUTER, PUMPS, VALVES, ETC)	—		$150,000
O&M COSTS (ANALYSIS AND REPORTING), $/DAY			
1 SAMPLE/DAY (BASED ON 30 MAN-HOURS FOR 22 LAB ANALYSES @ $27/M-H.)	$800		$260
6 SAMPLES/DAY (BASED ON 75 MAN-HOURS FOR 22 LAB ANALYSES @ $27/M-H.)	$2,000		$260
MINIMUM CAPITAL PAYOUT TIME FOR AUTOMATION, DAYS			
1 SAMPLE/DAY	—		278 DAYS
6 SAMPLES/DAY	—		86 DAYS

As can be readily inferred from this report, automated monitoring technology is not limited to terrestrial potable or wastewater monitoring, but is also applicable for monitoring water reuse in a space environment (an original and continuing point of interest in conducting the study). Potential applications of the technology include monitoring drinking water on aircraft and ships (to minimize or eliminate outbreak of dysentery on cruises) and industrial plant discharges. With additional sensors the concept could even be used to monitor runoffs from pesticides and herbicides applications on farms and forests to help control contamination of streams and lakes. The potential appears bright for regional monitoring of water quality to provide data for total management of regional water resources.

REFERENCES

1. "Boeing/NASA Water Monitor System Computer Operating Manual," Volumes I and II, D2-118621-1A, Poel, September 11, 1978.

2. "National Interim Primary Drinking Water Regulations," EPA-570/9-76-003.

3. "Advanced Treatment for Wastewater Reclamation at Water Factory 21," McCarty et al, EPA Technical Report Number 236, January 1980.

4. "Water Monitor System Technical Summary Report," Jeffers, Brooks, Thomas, Nibley, and Poel, The Boeing Company, September 26, 1979.

5. EPA Grant R804431, Stanford University From Robert S. Kerr Environmental Lab.

6. "Schaum's Outline of Theory and Problems of Statistics," Spiegel, Rensselear Polytechnic Institute, McGraw-Hill Book Company.

7. "Statistical Package for the Social Sciences," Nie, et al, McGraw-Hill Book Company, Second Edition, 1975.

8. "Operation and Maintenance Manual for the Water Reclamation Plant at Palo Alto, California," Santa Clara Valley Water District, Santa Clara County, California, December 1977. Jenks and Harrison.

9. "Wastewater Reclamation Requirements for the Santa Clara County Flood Control and Water District and the City of Palo Alto for Direct Injection of Reclaimed Wastewater into the upper aquifer of the Santa Clara Valley Groundwater Basin near Palo Alto," Order Number 73-71, and correspondence dated August 23, 1977, California Regional Water Quality Control Board, San Francisco Bay Region.

10. "National Interim Primary Drinking Water Regulations Control of Trihalomethanes in Drinking Water." Environmental Protection Agency 40CFR, Part 141, pp. 68624-68707, Federal Register Volume 44, Number 231, Thursday, November 29, 1979, Rules and Regulations.

11. "European Standards for Drinking Water," 2nd. Ed. 1970. World Health Organization.

12. "Guidelines for Interpretation of Water Quality for Agriculture," University of California Cooperative Extension, UC - Committee of Consultants, January 15, 1975.

13. "California Domestic Water Quality and Monitoring Regulations," California Health and Safety Code. Section 4026, Division 5, Part 1, Chapter 7 Water and Water Systems, California Administrative Code. Articles 1-8, pp. 1-701-1719, 1977.

14. "Final Report on Water/Wastewater Management User Requirements Committee Meeting of February 14, 1974," Public Technology Incorporated for NASA Office of Applications, July 15, 1974.

15. "NASA JSC Water Monitor System - City of Houston Field Demonstration," Taylor et al, July 1979. NASA Reference Publication 1041.

APPENDIX A

STATISTICAL ANALYSIS COEFFICIENTS

This section contains the results of statistical analyses of the WMS data. Included are (1) the slope, intercept, and chi square for the lognormal data distribution model, and (2) slope, intercept, and correlation coefficients for process output as a function of input for linear, parabolic and logarithmic regression models.

PAGE

Test Period A

GC Data . . . .

Other Data . . . .

Test Period H

GC Data . . . .

Other Data . . . .

Test Period A

Plant Parameters . . . .

```
LOG-NORMAL DISTRIBUTION:  SEP  3, 1980 TO SEP 30, 1980

SAMPLE   MONTHLY         ONE                LOG(Y)=F(Z)               CHI        SAMPLE
SOURCE   AVERAGE        SIGMA          SLOPE       INTERCEPT         SQUARE       SIZE

TETRACHLOROETHYLENE

   1          3.5          2.0      0.2879E  0  0.4924E  0    27.0000        18
   2          3.2          2.2      0.3207E  0  0.4405E  0     8.1429        14
   3          4.9          0.8      0.7044E -1  0.6884E  0     2.3333         6
   4          3.8          2.0      0.2918E  0  0.5265E  0     9.5714        14
   5          3.7          2.0      0.2887E  0  0.5082E  0     5.2857        14
   6          3.3          2.1      0.2946E  0  0.4625E  0     6.2353        17

METHYLENE CHLORIDE

   1         21.8         17.6      0.3239E  0  0.1224E  1     2.5556        18
   2         10.7          6.3      0.2498E  0  0.9629E  0     1.0000        14
   3         18.5          8.6      0.2639E  0  0.1211E  1     4.0000         6
   4         14.7          6.5      0.2335E  0  0.1116E  1     4.5714        14
   5         12.6          8.6      0.3205E  0  0.1001E  1     1.0000        14
   6         11.7          6.3      0.2718E  0  0.9995E  0     0.9412        17

CHLOROFORM

   1         12.0          3.6      0.1239E  0  0.1062E  1     0.8889        18
   2         22.5         18.2      0.2626E  0  0.1263E  1     8.1429        14
   3         13.3          4.2      0.1183E  0  0.1110E  1     5.6667         6
   4         16.2         11.1      0.2413E  0  0.1137E  1     8.1429        14
   5         21.0          6.6      0.1364E  0  0.1303F  1     6.7143        14
   6         24.2          7.5      0.1345E  0  0.1364E  1     2.7059        17

1,1,1-TRICHLOROETHANE

   1          1.6          0.9      0.2030E  0  0.1774E  0     8.1111        18
   2          0.8          0.3      0.5686E -1  0.2541E -1    24.5714        14
   3          0.5          0.0      0.0000E  0  0.0000E  0    24.0000         6
   4          0.4          0.1      0.0000E  0  0.0000E  0    56.0000        14
   5          3.2          1.0      0.1684E  0  0.4833E  0    15.2857        14
   6          3.5          0.9      0.1206E  0  0.5298E  0    15.6471        17

BROMODICHLOROMETHANE

   1         15.3          6.8      0.2251E  0  0.1137E  1     5.8889        18
   2         24.4         14.2      0.2335E  0  0.1328E  1     8.8571        14
   3         19.4          6.3      0.1338E  0  0.1269E  1     0.6667         6
   4         21.1          9.0      0.1644E  0  0.1294E  1     3.8571        14
   5         20.2          5.3      0.1505E  0  0.1285E  1     3.1429        14
   6         20.1          7.0      0.2367E  0  0.1260E  1    17.4118        17

EOF..
```

```
LOG-NORMAL DISTRIBUTION:  SEP  3, 1980 TO SEP 30, 1980

SAMPLE   MONTHLY         ONE           LOG(Y)=F(Z)             CHI       SAMPLE
SOURCE   AVERAGE        SIGMA       SLOPE      INTERCEPT       SQUARE      SIZE

TRICHLOROETHYLENE

   1          1.7         0.9     0.1930E  0  0.1833E  0     3.1111       18
   2          1.0         0.3     0.7301E -1  0.4955E -1     6.0000       14
   3          0.9         0.3     0.6559E -1  0.3128E -1     4.0000        6
   4          0.7         0.2     0.1534E -1  0.6028E -2    38.8571       14
   5          1.7         0.3     0.7605E -1  0.2226E  0     2.4286       14
   6          1.8         0.3     0.6430E -1  0.2621E  0     1.5294       17

DIBROMOCHLOROMETHANE

   1          8.9         5.3     0.2952E  0  0.8686E  0     1.4444       18
   2         13.4         7.6     0.2366E  0  0.1067E  1     6.7143       14
   3         10.3         5.5     0.2121E  0  0.9662E  0     0.6667        6
   4         13.7         7.3     0.2413E  0  0.1078E  1     0.2857       14
   5          9.3         2.3     0.1063E  0  0.9550E  0     4.5714       14
   6         13.4         3.9     0.1348E  0  0.1109E  1     4.4706       17

BROMOFORM

   4          0.1         0.3     0.1521E -1  0.4065E -2    46.7143       14

TRIHALOMETHANES

   1         36.3        14.9     0.1880E  0  0.1524E  1     8.1111       18
   2         60.4        37.7     0.2171E  0  0.1722E  1     8.8571       14
   3         43.0        15.7     0.1425E  0  0.1612E  1     0.6667        6
   4         51.1        25.4     0.1912E  0  0.1667E  1     0.2857       14
   5         50.4        11.1     0.9698E -1  0.1693E  1     4.5714       14
   6         57.8         9.8     0.7596E -1  0.1756E  1     3.2941       17

TOTAL HALOCARBONS

   1         64.8        18.9     0.1326E  0  0.1793E  1     1.4444       18
   2         76.1        34.3     0.1625E  0  0.1850E  1     3.1429       14
   3         67.9        18.1     0.1168E  0  0.1819E  1     2.3333        6
   4         70.7        23.8     0.1335E  0  0.1829E  1     1.7143       14
   5         71.6         9.7     0.5948E -1  0.1851E  1     0.2857       14
   6         78.2        11.3     0.6472E -1  0.1889E  1     1.5294       17
EOF..
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3, 1980 TO SEP 30, 1980

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 2

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL       COMPOUND                  A0          A1       STANDARD      CORR.      SAMPLE
NO.                                                       ERROR       COEFF.       SIZE

  1. TETRACHLOROETHYLENE          -0.0053      1.0276      0.7142      0.9211        14
  2. METHYLENE CHLORIDE            7.3039      0.1985      5.5127      0.3482        16
  3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000         0
  4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000         0
  5. CHLOROFORM                  -10.5012      2.5546     14.2211      0.5685        16
  6. 1,1,1-TRICHLOROETHANE         0.5719      0.1755      0.2802      0.5256        16
  7. BROMODICHLOROMETHANE         11.8713      0.7395     12.1173      0.4427        16
  8. TRICHLOROETHYLENE             0.5403      0.3087      0.1931      0.8220        16
  9. DIBROMOCHLOROMETHANE          8.0894      0.5119      6.4290      0.4864        16
 10. BROMOFORM                     0.0472     -0.1046      0.0649      0.9733         6
 11. TRIHALOMETHANES              24.5236      0.8770     32.3869      0.4482        16
 12. TOTAL HALOCARBONS            64.1609      0.1626     31.4483      0.3309        16

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL       COMPOUND                  A0          A1          A2       STANDARD      CORR.
NO.                                                                   ERROR       COEFF.

  1. TETRACHLOROETHYLENE          -0.2633      1.3493     -0.0575      0.7026      0.9237
  2. METHYLENE CHLORIDE            4.1567      0.6159     -0.0098      5.3975      0.3970
  3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                   36.3777     -4.4606      0.2424     13.7551      0.6057
  6. 1,1,1-TRICHLOROETHANE         0.0004      0.9866     -0.2117      0.2502      0.6503
  7. BROMODICHLOROMETHANE         48.5544     -4.0770      0.1379     11.4380      0.5326
  8. TRICHLOROETHYLENE             0.3153      0.5797     -0.0636      0.1877      0.8327
  9. DIBROMOCHLOROMETHANE         23.0442     -2.4709      0.1191      6.0244      0.5742
 10. BROMOFORM                     0.0494     -0.2153      0.4531      0.0648      0.9733
 11. TRIHALOMETHANES             204.9743     -8.4732      0.1080     29.6396      0.5751
 12. TOTAL HALOCARBONS           187.1273     -4.3741      0.0383     30.6693      0.3912

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL       COMPOUND                  A0          A1       STANDARD      CORR.
NO.                                                       ERROR       COEFF.

  1. TETRACHLOROETHYLENE          -0.1553      1.2270      0.2923      0.8595
  2. METHYLENE CHLORIDE            0.4414      0.4626      0.2013      0.5637
  3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                   -0.1944      1.3306      0.1928      0.7549
  6. 1,1,1-TRICHLOROETHANE        -0.1508      0.3881      0.1234      0.6645
  7. BROMODICHLOROMETHANE          0.5590      0.6483      0.1850      0.6556
  8. TRICHLOROETHYLENE            -0.0852      0.5217      0.0759      0.8320
  9. DIBROMOCHLOROMETHANE          0.6165      0.4728      0.1934      0.6376
 10. BROMOFORM                    -1.5453      0.2502      0.7440      0.8875
 11. TRIHALOMETHANES               0.7312      0.6284      0.1765      0.6663
 12. TOTAL HALOCARBONS             1.4753      0.2064      0.1483      0.5287
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3. 1980 TO SEP 30. 1980

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 3

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL       COMPOUND                    A0         A1      STANDARD    CORR.     SAMPLE
NO.                                                        ERROR     COEFF.     SIZE

 1. TETRACHLOROETHYLENE             1.7101     0.7099     0.3969     0.7844        8
 2. METHYLENE CHLORIDE             25.6407    -0.2844    11.0371     0.2916        8
 3. CARBON TETRACHLORIDE            0.0000     0.0000     0.0000     0.0000        0
 4. 1,2-DICHLOROETHYLENE            0.0000     0.0000     0.0000     0.0000        0
 5. CHLOROFORM                      5.0548     0.6638     3.1839     0.3667        8
 6. 1,1,1-TRICHLOROETHANE           0.3173     0.1045     0.1047     0.6925        8
 7. BROMODICHLOROMETHANE            0.2896     1.0344     4.1727     0.7544        7
 8. TRICHLOROETHYLENE               0.3762     0.2651     0.0938     0.9340        8
 9. DIBROMOCHLOROMETHANE            5.4802     0.6647     4.9273     0.5133        8
10. BROMOFORM                       0.0000     0.0000     0.0000     0.0000        0
11. TRIHALOMETHANES                 2.7811     1.0101     8.2680     0.7788        8
12. TOTAL HALOCARBONS              63.5411     0.0607    16.4995     0.0656        8

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL       COMPOUND                    A0         A1         A2      STANDARD     CORR.
NO.                                                                   ERROR      COEFF.

 1. TETRACHLOROETHYLENE             2.5636     0.3195     0.0435     0.3960     0.7855
 2. METHYLENE CHLORIDE             27.0611    -0.4777     0.0044    11.0178     0.2970
 3. CARBON TETRACHLORIDE            0.0000     0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE            0.0000     0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                     59.0891    -8.9989     0.4200     2.9451     0.5094
 6. 1,1,1-TRICHLOROETHANE           0.2854     0.1444    -0.0097     0.1045     0.6936
 7. BROMODICHLOROMETHANE           33.2003    -3.2055     0.1279     3.5858     0.8257
 8. TRICHLOROETHYLENE               0.4329     0.2056     0.0128     0.0934     0.9347
 9. DIBROMOCHLOROMETHANE           17.6994    -1.6860     0.0891     4.7274     0.5675
10. BROMOFORM                       0.0000     0.0000     0.0000     0.0000     0.0000
11. TRIHALOMETHANES                89.4935    -3.6054     0.0572     5.2451     0.9174
12. TOTAL HALOCARBONS              66.2818    -0.0416     0.0009    16.4986     0.0664

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL       COMPOUND                    A0         A1      STANDARD    CORR.
NO.                                                        ERROR     COEFF.

 1. TETRACHLOROETHYLENE             0.2778     0.6314     0.0368     0.7712
 2. METHYLENE CHLORIDE              1.4021    -0.1448     0.2639     0.3250
 3. CARBON TETRACHLORIDE            0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE            0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                      0.6590     0.4123     0.0908     0.3347
 6. 1,1,1-TRICHLOROETHANE          -0.3872     0.3817     0.0769     0.7634
 7. BROMODICHLOROMETHANE            0.2784     0.7852     0.0961     0.7067
 8. TRICHLOROETHYLENE              -0.2046     0.5664     0.0419     0.9376
 9. DIBROMOCHLOROMETHANE            0.5221     0.5303     0.1876     0.4760
10. BROMOFORM                       0.0000     0.0000     0.0000     0.0000
11. TRIHALOMETHANES                 0.5001     0.6995     0.0885     0.6852
12. TOTAL HALOCARBONS               1.7290     0.0484     0.1076     0.1368
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3, 1980 TO SEP 30, 1980

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                  A0          A1      STANDARD     CORR.       SAMPLE
NO.                                                        ERROR      COEFF.       SIZE

 1. TETRACHLOROETHYLENE            0.7240      0.9178      0.6016     0.9261         13
 2. METHYLENE CHLORIDE            11.9398      0.1974      5.9786     0.3436         15
 3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000     0.0000          0
 4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000     0.0000          0
 5. CHLOROFORM                    -7.5730      1.9074      8.2087     0.6259         15
 6. 1,1,1-TRICHLOROETHANE          0.3805      0.0283      0.1117     0.3281         15
 7. BROMODICHLOROMETHANE          17.0459      0.1741      8.7111     0.1217         16
 8. TRICHLOROETHYLENE              0.4244      0.1789      0.0959     0.8598         16
 9. DIBROMOCHLOROMETHANE          11.9686      0.1034      6.9163     0.0725         16
10. BROMOFORM                      0.3088     -1.3522      0.3995     0.3658          6
11. TRIHALOMETHANES               37.6208      0.2608     24.5619     0.1416         16
12. TOTAL HALOCARBONS             71.9516     -0.0888     25.1785     0.0601         16

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                  A0          A1          A2      STANDARD     CORR.
NO.                                                                    ERROR      COEFF.

 1. TETRACHLOROETHYLENE            0.2490      1.4184     -0.0859      0.5701     0.9339
 2. METHYLENE CHLORIDE             9.6272      0.4925     -0.0068      5.9273     0.3649
 3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000      0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000      0.0000     0.0000
 5. CHLOROFORM                    22.6449     -2.5968      0.1541      7.8788     0.6630
 6. 1,1,1-TRICHLOROETHANE          0.3453      0.0788     -0.0131      0.1115     0.3340
 7. BROMODICHLOROMETHANE          52.4386     -4.4730      0.1331      7.8094     0.4563
 8. TRICHLOROETHYLENE              0.4064      0.2006     -0.0051      0.0959     0.8600
 9. DIBROMOCHLOROMETHANE          15.2089     -0.5428      0.0258      6.8991     0.1008
10. BROMOFORM                      0.3447     -3.0151      6.9416      0.3986     0.3710
11. TRIHALOMETHANES              176.6369     -6.9424      0.0832     22.4088     0.4293
12. TOTAL HALOCARBONS            214.1011     -5.3332      0.0443     23.8599     0.3244

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                  A0          A1      STANDARD     CORR.
NO.                                                        ERROR      COEFF.

 1. TETRACHLOROETHYLENE           -0.1028      1.2365      0.1118     0.9677
 2. METHYLENE CHLORIDE             0.8066      0.2885      0.2091     0.3683
 3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000     0.0000
 5. CHLOROFORM                    -0.2637      1.2961      0.1807     0.6314
 6. 1,1,1-TRICHLOROETHANE         -0.4047      0.1418      0.1077     0.3432
 7. BROMODICHLOROMETHANE           1.1932      0.0592      0.1693     0.2129
 8. TRICHLOROETHYLENE             -0.2246      0.4186      0.0601     0.8337
 9. DIBROMOCHLOROMETHANE           0.9629      0.0940      0.2318     0.2666
10. BROMOFORM                     -1.8066     -0.2345      0.8201     0.5193
11. TRIHALOMETHANES                1.5922      0.0220      0.2092     0.2409
12. TOTAL HALOCARBONS              2.0972     -0.1756      0.1886     0.2206
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3. 1980 TO SEP 30. 1980

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                 A0         A1      STANDARD     CORR.      SAMPLE
NO.                                                     ERROR       COEFF.      SIZE

 1. TETRACHLOROETHYLENE          1.2896     0.7442     0.9736     0.7740        13
 2. METHYLENE CHLORIDE           7.5962     0.3025     7.3864     0.3847        16
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000         0
 4. 1,2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000         0
 5. CHLOROFORM                   6.0647     1.2280     4.9020     0.6575        15
 6. 1,1,1-TRICHLOROETHANE        3.1592     0.0713     0.8724     0.1465        16
 7. BROMODICHLOROMETHANE        13.8779     0.3989     4.1878     0.5421        16
 8. TRICHLOROETHYLENE            1.5019     0.1037     0.2700     0.4839        16
 9. DIBROMOCHLOROMETHANE         8.5901     0.0048     2.0740     0.4345        16
10. BROMOFORM                    0.0028     0.1614     0.0000     1.0006         2
11. TRIHALOMETHANES             29.6752     0.5283     9.1079     0.6843        16
12. TOTAL HALOCARBONS           57.6578     0.2163     8.8952     0.5449        16

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                 A0         A1         A2      STANDARD     CORR.
NO.                                                                ERROR       COEFF.

 1. TETRACHLOROETHYLENE          1.2695     0.7623    -0.0030     0.9736     0.7740
 2. METHYLENE CHLORIDE          10.3133    -0.0578     0.0084     7.3227     0.4033
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                  10.1066     0.6272     0.0207     4.8918     0.6593
 6. 1,1,1-TRICHLOROETHANE        3.8727    -0.9415     0.2643     0.8581     0.2310
 7. BROMODICHLOROMETHANE        12.6160     0.5646    -0.0047     4.1855     0.5428
 8. TRICHLOROETHYLENE            1.3130     0.3313    -0.0534     0.2673     0.4993
 9. DIBROMOCHLOROMETHANE        11.1539    -0.4266     0.0204     2.0380     0.4655
10. BROMOFORM                    0.0000     0.0000     0.0000     0.0130     1.0111
11. TRIHALOMETHANES             29.7285     0.5255     0.0000     9.1079     0.6843
12. TOTAL HALOCARBONS           -6.5184     2.5840    -0.0200     8.1206     0.6435

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                 A0         A1      STANDARD     CORR.
NO.                                                     ERROR       COEFF.

 1. TETRACHLOROETHYLENE          0.1692     0.7616     0.1136     0.8693
 2. METHYLENE CHLORIDE           0.6098     0.3480     0.2836     0.3980
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                   0.5675     0.6867     0.1097     0.5918
 6. 1,1,1-TRICHLOROETHANE        0.4830     0.0662     0.1534     0.2539
 7. BROMODICHLOROMETHANE         0.8227     0.3969     0.1212     0.5390
 8. TRICHLOROETHYLENE            0.1917     0.1424     0.0854     0.4911
 9. DIBROMOCHLOROMETHANE         0.8807     0.0870     0.0972     0.4849
10. BROMOFORM                   -1.0403     0.6896     0.0000     1.0000
11. TRIHALOMETHANES              1.0151     0.4303     0.0843     0.6901
12. TOTAL HALOCARBONS            1.5057     0.1928     0.0547     0.5871
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3. 1980 TO SEP 30. 1980

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                 A0          A1       STANDARD     CORR.       SAMPLE
NO.                                                        ERROR      COEFF.       SIZE

 1. TETRACHLOROETHYLENE          -0.0076      0.9757      0.8872      0.8722        14
 2. METHYLENE CHLORIDE           10.6397      0.0515      6.2819      0.0849        16
 3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000         0
 4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000         0
 5. CHLOROFORM                   12.3811      0.7540      5.4056      0.5037        16
 6. 1,1,1-TRICHLOROETHANE         3.5738     -0.1115      0.8223      0.1673        16
 7. BROMODICHLOROMETHANE         19.9281      0.1178      4.0332      0.4466        16
 8. TRICHLOROETHYLENE             1.9047     -0.0501      0.2925      0.1527        16
 9. DIBROMOCHLOROMETHANE         12.3085      0.0225      4.0081      0.1290        16
10. BROMOFORM                     0.2420     -2.6727      0.0619      0.9000         3
11. TRIHALOMETHANES              51.8378      0.1126     10.8929      0.1430        16
12. TOTAL HALOCARBONS            85.2053     -0.1508     12.2909      0.2142        16

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                 A0          A1          A2       STANDARD     CORR.
NO.                                                                    ERROR      COEFF.

 1. TETRACHLOROETHYLENE          -0.2184      1.2385     -0.0470      0.8811      0.8741
 2. METHYLENE CHLORIDE           11.6885     -0.0876      0.0033      6.2707      0.1036
 3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000      0.0000
 4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000      0.0000
 5. CHLOROFORM                   21.0830     -0.5482      0.0450      5.3639      0.5150
 6. 1,1,1-TRICHLOROETHANE         5.3978     -2.7004      0.6756      0.7170      0.5108
 7. BROMODICHLOROMETHANE         17.6954      0.4110     -0.0084      4.0258      0.4499
 8. TRICHLOROETHYLENE             1.8414      0.0263     -0.0179      0.2923      0.1586
 9. DIBROMOCHLOROMETHANE          8.3565      0.8107     -0.0315      3.9639      0.1954
10. BROMOFORM                     0.6606    -30.5320    256.1277      0.0000      1.0000
11. TRIHALOMETHANES              55.5942     -0.0821      0.0022     10.8895      0.1451
12. TOTAL HALOCARBONS           139.5964     -2.1575      0.0170     11.8995      0.3251

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                 A0          A1       STANDARD     CORR.
NO.                                                        ERROR      COEFF.

 1. TETRACHLOROETHYLENE          -0.1527      1.1982      0.1700      0.9429
 2. METHYLENE CHLORIDE            0.8138      0.1541      0.2648      0.3263
 3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000
 4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000
 5. CHLOROFORM                    0.8760      0.4117      0.1141      0.5147
 6. 1,1,1-TRICHLOROETHANE         0.5309     -0.1006      0.1135      0.3071
 7. BROMODICHLOROMETHANE          1.2170      0.0972      0.0796      0.4053
 8. TRICHLOROETHYLENE             0.2630     -0.0509      0.0711      0.1712
 9. DIBROMOCHLOROMETHANE          1.0242      0.0532      0.1446      0.2789
10. BROMOFORM                    -4.2520     -1.9939      0.0165      0.9997
11. TRIHALOMETHANES               1.6098      0.0838      0.0879      0.1900
12. TOTAL HALOCARBONS             2.1021     -0.1287      0.0723      0.2664
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3, 1980 TO SEP 30, 1980

FROM SAMPLE SOURCE 2 TO SAMPLE SOURCE 3

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL       COMPOUND                 A0          A1       STANDARD     CORR.      SAMPLE
NO.                                                       ERROR      COEFF.      SIZE

 1. TETRACHLOROETHYLENE          2.3183      0.5244      0.4747     0.6704         8
 2. METHYLENE CHLORIDE          20.8605     -0.0196     11.5376     0.0114         8
 3. CARBON TETRACHLORIDE         0.0000      0.0000      0.0000     0.0000         0
 4. 1,2-DICHLOROETHYLENE         0.0000      0.0000      0.0000     0.0000         0
 5. CHLOROFORM                   4.1122      0.5622      1.4243     0.9093         8
 6. 1,1,1-TRICHLOROETHANE        0.2100      0.3847      0.0978     0.7386         8
 7. BROMODICHLOROMETHANE         2.3490      0.7279      3.2504     0.8594         7
 8. TRICHLOROETHYLENE            0.0126      0.8022      0.0658     0.9681         8
 9. DIBROMOCHLOROMETHANE         1.5738      0.8480      2.3854     0.9096         8
10. BROMOFORM                    0.0000      0.0000      0.0000     0.0000         0
11. TRIHALOMETHANES              6.7533      0.7098      5.7966     0.8981         8
12. TOTAL HALOCARBONS           29.5924      0.5706     13.5811     0.5704         8

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL       COMPOUND                 A0          A1          A2       STANDARD     CORR.
NO.                                                                   ERROR      COEFF.

 1. TETRACHLOROETHYLENE         16.3789     -5.2380      0.5741      0.3419     0.8453
 2. METHYLENE CHLORIDE          34.9632     -2.4557      0.0800     10.6766     0.3792
 3. CARBON TETRACHLORIDE         0.0000      0.0000      0.0000      0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE         0.0000      0.0000      0.0000      0.0000     0.0000
 5. CHLOROFORM                  19.5421     -1.1476      0.0411      1.0515     0.9516
 6. 1,1,1-TRICHLOROETHANE        0.2754      0.2385      0.0743      0.0976     0.7398
 7. BROMODICHLOROMETHANE        26.0396     -1.4305      0.0449      2.8117     0.8968
 8. TRICHLOROETHYLENE            0.2056      0.4651      0.1361      0.0642     0.9697
 9. DIBROMOCHLOROMETHANE         1.1091      0.9298     -0.0028      2.3838     0.9097
10. BROMOFORM                    0.0000      0.0000      0.0000      0.0000     0.0000
11. TRIHALOMETHANES             40.6906     -0.5597      0.0104      5.2003     0.9189
12. TOTAL HALOCARBONS          113.4089     -1.8003      0.0157     12.7843     0.6342

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL       COMPOUND                 A0          A1       STANDARD     CORR.
NO.                                                       ERROR      COEFF.

 1. TETRACHLOROETHYLENE          0.3604      0.4745      0.0464     0.5961
 2. METHYLENE CHLORIDE           1.2299      0.0089      0.2686     0.2711
 3. CARBON TETRACHLORIDE         0.0000      0.0000      0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE         0.0000      0.0000      0.0000     0.0000
 5. CHLOROFORM                   0.3395      0.6469      0.0521     0.8413
 6. 1,1,1-TRICHLOROETHANE       -0.2270      0.6480      0.0808     0.7348
 7. BROMODICHLOROMETHANE         0.1881      0.7979      0.0797     0.8096
 8. TRICHLOROETHYLENE           -0.0890      0.9665      0.0346     0.9578
 9. DIBROMOCHLOROMETHANE         0.1805      0.8165      0.1090     0.8595
10. BROMOFORM                    0.0000      0.0000      0.0000     0.0000
11. TRIHALOMETHANES              0.2901      0.7844      0.0660     0.8396
12. TOTAL HALOCARBONS            0.8633      0.5263      0.0941     0.4986
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3. 1980 TO SEP 30. 1980

FROM SAMPLE SOURCE 3 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                 A0          A1       STANDARD    CORR.      SAMPLE
NO.                                                       ERROR      COEFF.      SIZE

 1. TETRACHLOROETHYLENE          -1.0734      1.2210      0.1189      0.9969        8
 2. METHYLENE CHLORIDE           12.1293      0.2895      4.5235      0.7518        8
 3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000        0
 4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000        0
 5. CHLOROFORM                   -0.6456      0.9898      1.2466      0.9597        8
 6. 1,1,1-TRICHLOROETHANE         0.2202      0.3732      0.0473      0.7781        8
 7. BROMODICHLOROMETHANE          1.0832      0.8527      0.9636      0.9872        7
 8. TRICHLOROETHYLENE             0.1541      0.6901      0.1187      0.8455        8
 9. DIBROMOCHLOROMETHANE         -1.6398      1.2013      1.1834      0.9858        8
10. BROMOFORM                     0.0000      0.0000      0.3598      0.4139        1
11. TRIHALOMETHANES               7.3518      0.8442      9.5203      0.8007        8
12. TOTAL HALOCARBONS            26.1681      0.5862     11.5445      0.6446        8

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                 A0          A1          A2       STANDARD    CORR.
NO.                                                                   ERROR      COEFF.

 1. TETRACHLOROETHYLENE           2.0961     -0.0950      0.1343      0.1014     0.9977
 2. METHYLENE CHLORIDE            6.4783      0.9024     -0.0125      4.1224     0.7993
 3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000     0.0000
 5. CHLOROFORM                  -19.0453      3.4731     -0.0766      1.0667     0.9706
 6. 1,1,1-TRICHLOROETHANE         0.5524     -0.8738      1.0926      0.0395     0.8515
 7. BROMODICHLOROMETHANE          5.7154      0.3696      0.0114      0.8758     0.9895
 8. TRICHLOROETHYLENE            -0.3566      1.7805     -0.5362      0.1122     0.8632
 9. DIBROMOCHLOROMETHANE          2.8014      0.3876      0.0298      0.9967     0.9899
10. BROMOFORM                     0.0000      0.0000      0.0000      0.3598     0.4139
11. TRIHALOMETHANES              20.2384      0.2762      0.0056      9.4808     0.8026
12. TOTAL HALOCARBONS           151.0085     -3.2522      0.0278      9.8706     0.7568

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                 A0          A1       STANDARD    CORR.
NO.                                                       ERROR      COEFF.

 1. TETRACHLOROETHYLENE          -0.1378      1.1991      0.0112      0.9970
 2. METHYLENE CHLORIDE            0.7818      0.3638      0.1235      0.7167
 3. CARBON TETRACHLORIDE          0.0000      0.0000      0.0000      0.0000
 4. 1,2-DICHLOROETHYLENE          0.0000      0.0000      0.0000      0.0000
 5. CHLOROFORM                   -0.1508      1.1085      0.0459      0.9538
 6. 1,1,1-TRICHLOROETHANE        -0.2655      0.4075      0.0573      0.6655
 7. BROMODICHLOROMETHANE          0.0892      0.8980      0.0293      0.9814
 8. TRICHLOROETHYLENE            -0.0730      0.8695      0.0612      0.8624
 9. DIBROMOCHLOROMETHANE         -0.1010      1.1097      0.0480      0.9818
10. BROMOFORM                     0.0000      0.0000      0.4439      1.0321
11. TRIHALOMETHANES               0.1940      0.8810      0.0957      0.8170
12. TOTAL HALOCARBONS             0.8451      0.5297      0.0760      0.6160
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3. 1980 TO SEP 30. 1980

FROM SAMPLE SOURCE 4 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND               A0          A1       STANDARD      CORR.       SAMPLE
NO.                                                     ERROR       COEFF.       SIZE

 1. TETRACHLOROETHYLENE        -0.1953      1.0054      0.6083      0.8954         13
 2. METHYLENE CHLORIDE          2.0341      0.7084      6.6711      0.5665         15
 3. CARBON TETRACHLORIDE        0.0000      0.0000      0.0000      0.0000          0
 4. 1,2-DICHLOROETHYLENE        0.0000      0.0000      0.0000      0.0000          0
 5. CHLOROFORM                 15.4812      0.3426      5.2079      0.5853         14
 6. 1,1,1-TRICHLOROETHANE       1.0723      3.2287      0.8170      0.4361         15
 7. BROMODICHLOROMETHANE       17.0230      0.1293      4.7155      0.3235         16
 8. TRICHLOROETHYLENE           1.1923      0.6671      0.2568      0.5541         16
 9. DIBROMOCHLOROMETHANE        7.9301      0.1146      1.9595      0.5253         16
10. BROMOFORM                  -0.0935     14.1360      0.0000      1.0000          2
11. TRIHALOMETHANES            42.6913      0.1543     10.9053      0.4876         16
12. TOTAL HALOCARBONS          70.7004      0.0000      9.6317      0.4191         16

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND               A0          A1          A2       STANDARD     CORR.
NO.                                                                 ERROR      COEFF.

 1. TETRACHLOROETHYLENE        -0.0746      0.9240      0.0112      0.6070      0.8956
 2. METHYLENE CHLORIDE          4.4064      0.3342      0.0122      6.6421      0.5717
 3. CARBON TETRACHLORIDE        0.0000      0.0000      0.0000      0.0000      0.0000
 4. 1,2-DICHLOROETHYLENE        0.0000      0.0000      0.0000      0.0000      0.0000
 5. CHLOROFORM                 12.9985      0.6359     -0.0060      5.1814      0.5910
 6. 1,1,1-TRICHLOROETHANE       2.2583      1.4590      1.0094      0.8165      0.4373
 7. BROMODICHLOROMETHANE       21.6702     -0.2306      0.0070      4.6769      0.3453
 8. TRICHLOROETHYLENE          -1.3090      7.3799     -4.2210      0.2074      0.7403
 9. DIBROMOCHLOROMETHANE        6.3314      0.3805     -0.0086      1.9230      0.5496
10. BROMOFORM                   0.0000      0.0000      0.0000      0.0130      1.0111
11. TRIHALOMETHANES            47.5377     -0.0416      0.0016     10.0551      0.4947
12. TOTAL HALOCARBONS          71.5061     -0.0250      0.0002      9.6305      0.4194

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND               A0          A1       STANDARD      CORR.
NO.                                                     ERROR       COEFF.

 1. TETRACHLOROETHYLENE        -0.1447      1.1044      0.0744      0.9501
 2. METHYLENE CHLORIDE          0.2031      0.7150      0.2550      0.5537
 3. CARBON TETRACHLORIDE        0.0000      0.0000      0.0000      0.0000
 4. 1,2-DICHLOROETHYLENE        0.0000      0.0000      0.0000      0.0000
 5. CHLOROFORM                  0.9563      0.3046      0.1107      0.5855
 6. 1,1,1-TRICHLOROETHANE       0.7125      0.5033      0.1437      0.4701
 7. BROMODICHLOROMETHANE        1.1501      0.1123      0.1365      0.3164
 8. TRICHLOROETHYLENE           0.2825      0.4353      0.0776      0.6115
 9. DIBROMOCHLOROMETHANE        0.7873      0.1669      0.0906      0.5785
10. BROMOFORM                  19.4776     10.0868      0.0000      1.0000
11. TRIHALOMETHANES             1.4633      0.1377      0.1004      0.5066
12. TOTAL HALOCARBONS           1.0592     -0.0075      0.0602      0.4530
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR SEP  3. 1980 TO SEP 30. 1980

FROM SAMPLE SOURCE 5 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                A0         A1      STANDARD     CORR.      SAMPLE
NO.                                                     ERROR      COEFF.      SIZE

 1. TETRACHLOROETHYLENE          0.2370     0.8472     1.1274     0.7763       15
 2. METHYLENE CHLORIDE           5.4775     0.5076     4.5263     0.6729       17
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000        0
 4. 1,2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000        0
 5. CHLOROFORM                   5.4030     0.7470     3.0206     0.9131       16
 6. 1,1,1-TRICHLOROETHANE        1.3072     0.6241     0.5680     0.7240       17
 7. BROMODICHLOROMETHANE        23.0625    -0.0986     5.3662     0.2114       17
 8. TRICHLOROETHYLENE            1.6281     0.1084     0.2814     0.2045       17
 9. DIBROMOCHLOROMETHANE         7.0567     0.5541     3.2826     0.5793       17
10. BROMOFORM                    0.0066     0.0081     0.0000     1.0000        2
11. TRIHALOMETHANES             46.2144     0.1089     9.9447     0.3857       17
12. TOTAL HALOCARBONS           66.4100     0.1345    12.0324     0.2206       17

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                A0         A1         A2      STANDARD     CORR.
NO.                                                                ERROR      COEFF.

 1. TETRACHLOROETHYLENE         -0.4063     1.4125    -0.0829     1.0935     0.7913
 2. METHYLENE CHLORIDE           4.5402     0.6096    -0.0059     4.5100     0.6757
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                  -0.3762     1.2190    -0.0083     2.8700     0.9214
 6. 1,1,1-TRICHLOROETHANE        2.2323    -0.0567     0.1115     0.5516     0.7432
 7. BROMODICHLOROMETHANE         1.0264     1.9546    -0.0438     3.8824     0.7071
 8. TRICHLOROETHYLENE            0.0713     0.8342    -0.1553     0.2669     0.3715
 9. DIBROMOCHLOROMETHANE        -7.0511     2.0099    -0.0740     2.6185     0.7598
10. BROMOFORM                    0.0000     0.0000     0.0000     0.1062     0.4816
11. TRIHALOMETHANES             21.6770     0.9379    -0.0047     9.2447     0.5142
12. TOTAL HALOCARBONS           62.3975     0.2240    -0.0004    12.0291     0.2218

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                A0         A1      STANDARD     CORR.
NO.                                                     ERROR      COEFF.

 1. TETRACHLOROETHYLENE         -0.4479     1.5966     0.1766     0.9362
 2. METHYLENE CHLORIDE           0.4735     0.5380     0.1902     0.7143
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                   0.2420     0.8177     0.0547     0.9255
 6. 1,1,1-TRICHLOROETHANE        0.2956     0.4433     0.0916     0.6229
 7. BROMODICHLOROMETHANE         1.4539    -0.1171     0.1471     0.1202
 8. TRICHLOROETHYLENE            0.2107     0.1873     0.0662     0.3277
 9. DIBROMOCHLOROMETHANE         0.4216     0.6696     0.1100     0.6650
10. BROMOFORM                   -1.3839     0.4490     0.0000     1.0000
11. TRIHALOMETHANES              1.2743     0.2743     0.0778     0.4590
12. TOTAL HALOCARBONS            1.5448     0.1787     0.0710     0.2546
```

```
LOG-NORMAL DISTRIBUTION:  SEP  3, 1980 TO FEB 28, 1981

SAMPLE                  ONE              LOG(Y)=F(Z)            CHI       SAMPLE
SOURCE   AVERAGE       SIGMA        SLOPE     INTERCEPT        SQUARE      SIZE

TOTAL BIOMASS

    1         2.0         1.1      0.3113E  0  0.2206E  0    11.8144       97
    2         0.2         0.1      0.2601E  0 -0.8346E  0     1.1379       58
    3         0.7         0.5      0.3149E  0 -0.2938E  0     3.5663       83
    4         0.3         0.3      0.2845E  0 -0.5782E  0     0.5556       90
    5         0.3         0.2      0.2731E  0 -0.6544E  0     6.3158       95
    6         0.3         0.4      0.2975E  0 -0.6705E  0     6.0870      115

VIABLE BIOMASS

    1         0.6         0.3      0.4343E  0 -0.3701E  0    32.6667       99
    2         0.0         0.0      0.3448E  0 -0.1698E  1     5.2759       58
    3         0.2         0.2      0.4553E  0 -0.8758E  0     6.4762       84
    4         0.1         0.1      0.4671E  0 -0.1127E  1     3.4506       91
    5         0.1         0.1      0.4719E  0 -0.1238E  1     1.4624       93
    6         0.1         0.4      0.4335E  0 -0.1167E  1     6.0690      116

RES CHLORINE

    1         4.0         1.9      0.2464E  0  0.5473E  0     5.5385       91
    2         1.5         1.0      0.3388E  0  0.4781E -1     0.6377       69
    3         1.2         1.1      0.3129E  0 -0.3173E -1     7.1282       78
    4         0.9         0.8      0.3433E  0 -0.1495E  0     1.9080       87
    5         0.3         0.5      0.3356E  0 -0.7382E  0    81.3627       91
    6         2.0         1.2      0.3085E  0  0.2194E  0    11.8654      104

TURBIDITY-SIO2

    1        13.9         5.2      0.1746E  0  0.1109E  1     5.9123      114
    2        11.4        10.0      0.2234E  0  0.9805E  0     9.1795       78
    3         6.2         3.9      0.2149E  0  0.7294E  0    20.0612       98
    4         9.3         3.5      0.1776E  0  0.9353E  0     7.6364      110
    5         5.7         4.0      0.1805E  0  0.7077E  0    22.1982      111
    6         4.7         1.8      0.1480E  0  0.6437E  0     6.2029      138

DIS OXYGEN

    1         6.2         1.8      0.1578E  0  0.7657E  0    38.5439      114
    2         6.7         1.3      0.8404E -1  0.8208E  0     7.7692       78
    3         6.6         1.6      0.1079E  0  0.8089E  0     8.0202       99
    4         6.9         1.6      0.9945E -1  0.8301E  0     3.9091      110
    5         6.3         1.4      0.9677E -1  0.7897E  0    10.7679      112
    6         6.2         1.6      0.1213E  0  0.7760E  0    18.5217      138

EOF..
```

```
LOG-NORMAL DISTRIBUTION:  SEP  3, 1980 TO FEB 28, 1981

SAMPLE                     ONE              LOG(Y)=F(Z)             CHI      SAMPLE
SOURCE   AVERAGE          SIGMA        SLOPE      INTERCEPT         SQUARE     SIZE

AMMONIA

   1         5.1          10.2      0.4780E  0  0.3761E  0     12.1136      88
   2         5.9          12.7      0.5348E  0  0.3245E  0      9.2281      57
   3         5.1          12.1      0.5726E  0  0.2350E  0      9.1316      76
   4         4.6          13.5      0.5400E  0  0.2077E  0     16.2222      81
   5         4.3          12.6      0.5916E  0  0.9275E -1     18.9722      72
   6         4.2          12.8      0.5163E  0  0.1283E  0     23.5670      97

PH

   1         5.6           0.5      0.3182E -1  0.7471E  0     14.0000     115
   2         7.4           1.0      0.5853E -1  0.8656E  0      0.4615      78
   3         6.0           0.7      0.4688E -1  0.7768E  0     18.5000     100
   4         6.3           0.8      0.4913E -1  0.7959E  0      5.5455     110
   5         6.2           0.6      0.4117E -1  0.7936E  0      6.9558     113
   6         6.1           0.5      0.3425E -1  0.7825E  0      6.3478     138

TOT ORG CARBON

   1         9.7           2.4      0.1108E  0  0.9753E  0     10.7708      96
   2         6.8           2.1      0.1377E  0  0.8107E  0     12.8824      68
   3         7.2           3.0      0.1536E  0  0.8293E  0     13.7531      81
   4         6.8           2.0      0.1278E  0  0.8145E  0     15.2222      90
   5         4.2           1.6      0.1448E  0  0.5945E  0      1.2527      91
   6         3.7           1.4      0.1306E  0  0.5524F  0      8.8113     106

CONDUCTIVITY

   1      1234.4          62.6      0.2145E -1  0.3091E  1      2.4348     115
   2      1287.1          85.3      0.2715E -1  0.3109E  1     12.3846      78
   3      1296.1          53.2      0.1837E -1  0.3112E  1      2.5000     100
   4      1303.8          60.4      0.2045E -1  0.3115E  1      3.9091     110
   5      1316.9          64.9      0.2156E -1  0.3119E  1      5.6283     113
   6      1313.3          65.5      0.2200E -1  0.3118E  1     11.3478     138

HARDNESS

   1       327.2         338.3      0.2237E  0  0.2430E  1     11.8750      80
   2       253.5         102.3      0.1415E  0  0.2379E  1      1.2647      68
   3       280.4         254.1      0.1782E  0  0.2396E  1      5.2791      86
   4       249.8          70.7      0.1259E  0  0.2380E  1      2.5263      95
   5       236.9          69.2      0.1315E  0  0.2355E  1      3.5306      98
   6       390.2         306.5      0.2368E  0  0.2514E  1     11.9551      89

SODIUM

   1       158.7          12.6      0.3403E -1  0.2199E  1      3.4815     108
   2       154.8          13.9      0.3757E -1  0.2188E  1      4.3947      76
   3       154.1          10.7      0.2968E -1  0.2187E  1      4.1505      93
   4       155.8          12.3      0.3364E -1  0.2191E  1      6.8544     103
   5       154.1          11.2      0.3112F -1  0.2187E  1      1.0962     104
   6       153.7          13.4      0.3650E -1  0.2185E  1      8.0000     130

EOF..
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 2

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR       UNITS              A0            A1       STANDARD      CORR.       SAMPLE
NO.                                                               ERROR       COEFF.       SIZE

  1. TOTAL BIOMASS MIL C/ML         0.1723        0.0040        0.1184       0.0560          56
  2. VIABLE BIOMASSMIL C/ML         0.0325       -0.0041        0.0363       0.0368          57
  5. RES CHLORINE  MG/L             0.8776        0.1345        0.9308       0.2636          66
  6. TURBIDITY-SIO2MG/L            -2.2882        1.0335        5.5174       0.6508          73
  7. DIS OXYGEN    MG/L             2.1952        0.7251        0.7302       0.8255          73
 10. AMMONIA       MG/L            -0.8645        1.0049        3.1423       0.9700          54
 11. NITRATE       MG/L             0.0000        0.0000        0.0000       0.0000           6
 12. PH            PH               6.3576        0.1949        0.9033       0.1181          73
 13. TOT ORG CARBON MG/L            2.8803        0.3952        1.7597       0.5354          64
 14. CONDUCTIVITY  MMMHO/CM       356.2761        0.7546       71.3212       0.4821          73
 15. TEMPERATURE#1 DEG F           33.7940        0.5293        1.0906       0.7552          73
 16. HARDNESS      MG/L           240.1208        0.0502      117.4959       0.1869          45
 17. SODIUM        MG/L            39.5770        0.7301       10.1351       0.6792          71
 20. AMBIENT TEMP  DEG F           15.9998        0.7821        0.9391       0.8237          81

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR       UNITS              A0            A1            A2       STANDARD      CORR.
NO.                                                                             ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML         0.0739        0.0979       -0.0170        0.1117       0.3352
  2. VIABLE BIOMASSMIL C/ML         0.0169        0.0628       -0.0521        0.0356       0.1911
  5. RES CHLORINE  MG/L             0.2534        0.4420       -0.0310        0.9092       0.3350
  6. TURBIDITY-SIO2MG/L            12.6343       -1.4599        0.0919        4.8211       0.7483
  7. DIS OXYGEN    MG/L             6.6462       -0.7201        0.1113        0.6432       0.8677
 10. AMMONIA       MG/L            -0.4301        0.8452        0.0034        3.1105       0.9706
 11. NITRATE       MG/L             0.0000        0.0000        0.0000        0.0000       0.0000
 12. PH            PH             -19.6378        8.4544       -0.6385        0.8100       0.4549
 13. TOT ORG CARBON MG/L            3.4184        0.2907        0.0047        1.7582       0.5365
 14. CONDUCTIVITY  MMMHO/CM      2399.9630       -2.5323        0.0013       71.1629       0.4856
 15. TEMPERATURE#1 DEG F         -262.8664        8.3916       -0.0519        0.5652       0.9423
 16. HARDNESS      MG/L           235.5657        0.0703       -0.0000      117.4644       0.1883
 17. SODIUM        MG/L          -340.0337        5.4264       -0.0144        9.5244       0.7241
 20. AMBIENT TEMP  DEG F          196.9927       -4.1842        0.0340        0.9283       0.8281

LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR       UNITS              A0            A1       STANDARD      CORR.
NO.                                                               ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML        -0.8367        0.0797        0.2437       0.2709
  2. VIABLE BIOMASSMIL C/ML        -1.6619        0.0892        0.3423       0.4601
  5. RES CHLORINE  MG/L            -0.1701        0.3857        0.3172       0.4284
  6. TURBIDITY-SIO2MG/L             0.1226        0.7926        0.1491       0.7400
  7. DIS OXYGEN    MG/L             0.3537        0.5961        0.0523       0.7694
 10. AMMONIA       MG/L            -0.1033        0.9115        0.2969       0.8986


 11. NITRATE       MG/L             0.0000        0.0000        0.0000       0.0000
 12. PH            PH               0.7282        0.1887        0.0523       0.1305
 13. TOT ORG CARBON MG/L            0.1808        0.6448        0.1122       0.6083
 14. CONDUCTIVITY  MMMHO/CM         0.9678        0.6927        0.0221       0.4928
 15. TEMPERATURE#1 DEG F            0.7944        0.5719        0.0063       0.7774
 16. HARDNESS      MG/L             2.0835        0.1216        0.1568       0.2536
 17. SODIUM        MG/L             0.5145        0.7619        0.0262       0.7086
 20. AMBIENT TEMP  DEG F            0.4138        0.7782        0.0056       0.8222
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 3

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR      UNITS            A0           A1      STANDARD     CORR.      SAMPLE
NO.                                                          ERROR      COEFF.       SIZE

  1, TOTAL BIOMASS MIL C/ML       0,1079       0,3042       0,4513      0,5157          81
  2, VIABLE BIOMASSMIL C/ML       0,0825       0,2571       0,2231      0,2947          82
  5, RES CHLORINE  MG/L           0,3698       0,1848       0,7693      0,3902          76
  6, TURBIDITY-SIO2MG/L           5,7514       0,0331       3,9211      0,0431          96
  7, DIS OXYGEN    MG/L           2,3042       0,6901       1,0738      0,7532          97
 10, AMMONIA       MG/L          -0,5690       1,0432       4,2268      0,9374          78
 11, NITRATE       MG/L           0,0000       0,0000
 12, PH            PH             4,1767       0,3283       0,7100      0,2069          98
 13, TOT ORG CARBON MG/L          0,4026       0,6978       2,3660      0,6034          78
 14, CONDUCTIVITY  MMMHO/CM     666,5134       0,5103      43,0356      0,5933          98
 15, TEMPERATURE#1 DEG F         27,0565       0,6194       1,1958      0,7961          97
 16, HARDNESS      MG/L         255,5196       0,0720     282,9058      0,0918          67
 17, SODIUM        MG/L          43,3484       0,7076       6,6844      0,7815          91
 20, AMBIENT TEMP  DEG F          2,9844       0,9613       0,6664      0,9281         108


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR      UNITS            A0           A1           A2     STANDARD     CORR.
NO.                                                                       ERROR     COEFF.

  1, TOTAL BIOMASS MIL C/ML       0,1543       0,2442       0,0153       0,4510     0,5164
  2, VIABLE BIOMASSMIL C/ML       0,1028       0,1678       0,0768       0,2229     0,2968
  5, RES CHLORINE  MG/L           1,0880      -0,2138       0,0467       0,7436     0,4560
  6, TURBIDITY-SIO2MG/L           1,1641       0,6788      -0,0205       3,8867     0,1388
  7, DIS OXYGEN    MG/L           3,9930       0,0605       0,0532       1,0525     0,7644
 10, AMMONIA       MG/L           1,5910       0,1198       0,0195       3,5892     0,9553
 11, NITRATE       MG/L           0,0000       0,0000       0,0000
 12, PH            PH            -9,6293       4,7598      -0,3487       0,6752     0,3666
 13, TOT ORG CARBON MG/L          7,1088      -0,5874       0,0574       2,2183     0,6641
 14, CONDUCTIVITY  MMMHO/CM    2246,8800      -2,0911       0,0011      42,3331     0,6108
 15, TEMPERATURE#1 DEG F       -182,6000       6,3134      -0,0386       0,8843     0,8941
 16, HARDNESS      MG/L         281,0149      -0,0331       0,0000     282,6165     0,1022
 17, SODIUM        MG/L        -119,2061       2,7285      -0,0062       6,5421     0,7919
 20, AMBIENT TEMP  DEG F       -119,5005       4,3275      -0,0231       0,6606     0,9294


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR      UNITS            A0           A1      STANDARD     CORR.
NO.                                                          ERROR      COEFF.

  1, TOTAL BIOMASS MIL C/ML      -0,4000       0,6161       0,2432      0,6550
  2, VIABLE BIOMASSMIL C/ML      -0,6220       0,5948       0,3591      0,6495
  5, RES CHLORINE  MG/L          -0,3201       0,4808       0,2700      0,5462
  6, TURBIDITY-SIO2MG/L           0,6655       0,0598       0,2135      0,2602
  7, DIS OXYGEN    MG/L           0,3620       0,5755       0,0677      0,7827
 10, AMMONIA       MG/L          -0,0567       0,8090       0,3851      0,8464


 11, NITRATE       MG/L           0,0000       0,0000
 12, PH            PH             0,4911       0,3822       0,0454      0,2681
 13, TOT ORG CARBON MG/L          0,0409       0,8111       0,1169      0,6434
 14, CONDUCTIVITY  MMMHO/CM       1,7026       0,4561       0,0149      0,5573
 15, TEMPERATURE#1 DEG F          0,6382       0,6553       0,0071      0,8117
 16, HARDNESS      MG/L           1,8394       0,2224       0,1814      0,4058
 17, SODIUM        MG/L           0,5817       0,7318       0,0182      0,7893
 20, AMBIENT TEMP  DEG F          0,0917       0,9513       0,0039      0,9201
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS            A0           A1        STANDARD     CORR.       SAMPLE
NO.                                                          ERROR       COEFF.        SIZE

  1. TOTAL BIOMASS MIL C/ML        0.2205       0.0555       0.2631      0.2326          90
  2. VIABLE BIOMASSMIL C/ML        0.0613       0.1169       0.1411      0.2369          91
  5. RES CHLORINE  MG/L            0.2948       0.1484       0.5808      0.4446          86
  6. TURBIDITY-SIO2MG/L            1.7246       0.5318       1.9104      0.8173         107
  7. DIS OXYGEN    MG/L            2.6516       0.6935       1.0570      0.7501         107
 10. AMMONIA       MG/L           -1.0612       1.0684       7.4770      0.8347          79
 11. NITRATE       MG/L            0.0000       0.0000
 12. PH            PH              2.7040       0.6380       0.7046      0.3870         108
 13. TOT ORG CARBON MG/L           1.7679       0.5133       1.5228      0.6404          89
 14. CONDUCTIVITY  MMMHO/CM      699.6809       0.4897      51.1653      0.5160         108
 15. TEMPERATURE#1 DEG F          25.5023       0.6406       1.2035      0.7914         106
 16. HARDNESS      MG/L          215.3553       0.0902      63.4912      0.4557          69
 17. SODIUM        MG/L           34.9676       0.7655       8.2540      0.7453         101
 20. AMBIENT TEMP  DEG F          14.1213       0.8103       0.8903      0.8466         116


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS            A0           A1           A2       STANDARD     CORR.
NO.                                                                      ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML        0.0917       0.1866      -0.0253      0.2581      0.3003
  2. VIABLE BIOMASSMIL C/ML        0.0444       0.1852      -0.0534      0.1409      0.2412
  5. RES CHLORINE  MG/L           -0.2028       0.3944      -0.0250      0.5589      0.5069
  6. TURBIDITY-SIO2MG/L           -0.2582       0.8368      -0.0103      1.8839      0.8228
  7. DIS OXYGEN    MG/L            4.9204      -0.1494       0.0714      1.0188      0.7705
 10. AMMONIA       MG/L            3.2914      -0.7325       0.0383      5.9875      0.8975
 11. NITRATE       MG/L            0.0000       0.0000       0.0000
 12. PH            PH             -6.2027       3.5043      -0.2263      0.6910      0.4270
 13. TOT ORG CARBON MG/L           4.5195      -0.0156       0.0238      1.4882      0.6608
 14. CONDUCTIVITY  MMMHO/CM     1424.3480      -0.6975       0.0005     51.0433      0.5194
 15. TEMPERATURE#1 DEG F        -176.7576       6.1265      -0.0371      0.9589      0.8734
 16. HARDNESS      MG/L          187.7379       0.2057      -0.0000     61.9280      0.4962
 17. SODIUM        MG/L         -134.2183       2.8652      -0.0065      8.1327      0.7540
 20. AMBIENT TEMP  DEG F          18.3300       0.6944       0.0008      0.8903      0.8466


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS            A0           A1        STANDARD     CORR.
NO.                                                          ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML       -0.6539       0.3462       0.2611      0.4935
  2. VIABLE BIOMASSMIL C/ML       -0.9340       0.5324       0.4103      0.6100
  5. RES CHLORINE  MG/L           -0.5263       0.6540       0.2941      0.5732
  6. TURBIDITY-SIO2MG/L           -0.0266       0.8589       0.0901      0.8639
  7. DIS OXYGEN    MG/L            0.4226       0.5289       0.0658      0.7553
 10. AMMONIA       MG/L           -0.0558       0.7367       0.3808      0.8317


 11. NITRATE       MG/L            0.0000       0.0000
 12. PH            PH              0.3204       0.6352       0.0444      0.4272
 13. TOT ORG CARBON MG/L           0.0768       0.7550       0.0948      0.6781
 14. CONDUCTIVITY  MMMHO/CM        1.7960       0.4267       0.0171      0.4807
 15. TEMPERATURE#1 DEG F           0.6126       0.4690       0.0071      0.7981
 16. HARDNESS      MG/L            1.7997       0.2345       0.1136      0.4606
 17. SODIUM        MG/L            0.4762       0.7806       0.0221      0.7545
 20. AMBIENT TEMP  DEG F           0.3891       0.7920       0.0053      0.8293
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS            A0          A1      STANDARD     CORR.      SAMPLE
NO.                                                        ERROR      COEFF.       SIZE

  1. TOTAL BIOMASS MIL C/ML       0.1675      0.0533      0.1941     0.2962         90
  2. VIABLE BIOMASSMIL C/ML       0.0222      0.1532      0.1317     0.3301         90
  5. RES CHLORINE  MG/L           0.3441     -0.0201      0.3844     0.1295         85
  6. TURBIDITY-SIO2MG/L           3.3918      0.1374      2.3581     0.3244        107
  7. DIS OXYGEN    MG/L           3.0606      0.5335      1.0376     0.6664        107
 10. AMMONIA       MG/L          -1.2794      0.9814      6.2969     0.8668         70
 12. PH            PH             2.2465      0.7067      0.4857     0.5595        107
 13. TOT ORG CARBON MG/L          1.1331      0.2999      1.4431     0.4383         87
 14. CONDUCTIVITY  MMMHO/CM     721.9695      0.4855     54.1132     0.4951        107
 16. HARDNESS      MG/L         217.8330      0.0665     65.1014     0.3455         70
 17. SODIUM        MG/L          43.7508      0.7005      7.2635     0.7609        101


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS            A0          A1          A2      STANDARD     CORR.
NO.                                                                    ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML       0.0834      0.1387     -0.0165      0.1912     0.3387
  2. VIABLE BIUMASSMIL C/ML       0.0202      0.1449      0.0065      0.1317     0.3302
  5. RES CHLORINE  MG/L           0.6911     -0.1886      0.0169      0.3698     0.2994
  6. TURBIDITY-SIO2MG/L           2.3653      0.2942     -0.0053      2.3522     0.3311
  7. DIS OXYGEN    MG/L           4.4187      0.0274      0.0430      1.0236     0.6774
 10. AMMONIA       MG/L           2.7893     -0.6875      0.0352      4.7852     0.9254
 12. PH            PH            -5.3227      3.1385     -0.1916      0.4716     0.5934
 13. TOT ORG CARBON MG/L          8.0260     -0.9603      0.0540      1.2990     0.5877
 14. CONDUCTIVITY  MMMHO/CM    1841.6540     -1.3530      0.0008     53.8423     0.5027
 16. HARDNESS      MG/L         200.0233      0.1410     -0.0000     64.4771     0.3690
 17. SODIUM        MG/L        -207.1806      3.8175     -0.0096      6.9521     0.7838


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS            A0          A1      STANDARD     CORR.
NO.                                                        ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML      -0.7185      0.3331      0.2373     0.4927
  2. VIABLE BIOMASSMIL C/ML      -1.0431      0.4975      0.4208     0.6052
  5. RES CHLORINE  MG/L          -0.6031     -0.2696      0.2970     0.6136
  6. TURBIDITY-SIO2MG/L           0.3123      0.3427      0.1426     0.5193
  7. DIS OXYGEN    MG/L           0.4463      0.4497      0.0727     0.6651
 10. AMMONIA       MG/L          -0.2108      0.7820      0.4439     0.8295
 12. PH            PH             0.2705      0.6968      0.0310     0.5951
 13. TOT ORG CARBON MG/L          0.1984      0.3960      0.1383     0.3385
 14. CONDUCTIVITY  MMMHO/CM       1.8547      0.4095      0.0179     0.4521
 16. HARDNESS      MG/L           1.9335      0.1754      0.1241     0.3200
 17. SODIUM        MG/L           0.5796      0.7318      0.0197     0.7739
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR      UNITS            A0           A1        STANDARD      CORR.       SAMPLE
NO.                                                           ERROR        COEFF.       SIZE

  1. TOTAL BIOMASS MIL C/ML        0.2141       0.0408       0.4055       0.1124          92
  2. VIABLE BIOMASSMIL C/ML        0.1577      -0.0368       0.3941       0.0291          93
  5. RES CHLORINE  MG/L            1.7591       0.0312       1.0366       0.1402          87
  6. TURBIDITY-SIO2MG/L            4.4161       0.0015       1.4865       0.1627         109
  7. DIS OXYGEN    MG/L            2.6872       0.5467       1.1081       0.6637         109
 10. AMMONIA       MG/L           -1.0724       1.0158       4.6056       0.8964          75
 11. NITRATE       MG/L            0.0000       0.0000       0.0000       0.0000           0
 12. PH            PH              4.0657       0.3535       0.4693       0.3327         110
 13. TOT ORG CARBON MG/L           1.5039       0.2310       1.3211       0.3777          87
 14. CONDUCTIVITY  MMMHO/CM      551.0430       0.6210      56.2356       0.5751         110
 15. TEMPERATURE#1 DEG F          30.3830       0.5749       1.1896       0.7684         109
 16. HARDNESS      MG/L          175.3407       0.6246     238.5027       0.7185          56
 17. SODIUM        MG/L           49.4841       0.6630       8.4651       0.6913         104
 20. AMBIENT TEMP  DEG F          20.7091       0.7181       1.0060       0.7813         119

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR      UNITS            A0           A1           A2        STANDARD      CORR.
NO.                                                                        ERROR        COEFF.

  1. TOTAL BIOMASS MIL C/ML        0.1043       0.1523      -0.0216       0.4032       0.1547
  2. VIABLE BIOMASSMIL C/ML        0.1541      -0.0222      -0.0113       0.3941       0.0294
  5. RES CHLORINE  MG/L            1.2779       0.2694      -0.0242       1.0254       0.2019
  6. TURBIDITY-SIO2MG/L            2.1270       0.3504      -0.0117       1.4407       0.2923
  7. DIS OXYGEN    MG/L            4.2649      -0.0540       0.0517       1.0877       0.6789
 10. AMMONIA       MG/L           -0.2078       0.6453       0.0088       4.5438       0.8993
 11. NITRATE       MG/L            0.0000       0.0000       0.0000       0.0000       0.0000
 12. PH            PH             -8.6666       4.4506      -0.3235       0.4266       0.5146
 13. TOT ORG CARBON MG/L           7.3318      -0.8341       0.0456       1.2102       0.5297
 14. CONDUCTIVITY  MMMHO/CM    -3142.5810       6.6745      -0.0025      53.3058       0.6314
 15. TEMPERATURE#1 DEG F        -129.0141       4.9116      -0.0294       1.0343       0.8310
 16. HARDNESS      MG/L          -37.9160       1.5098      -0.0004     208.3962       0.7941
 17. SODIUM        MG/L         -279.7527       4.7522      -0.0126       8.0106       0.7297
 20. AMBIENT TEMP  DEG F         151.2825      -2.8758       0.0247       1.0012       0.7837

LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR      UNITS            A0           A1        STANDARD      CORR.
NO.                                                           ERROR        COEFF.

  1. TOTAL BIOMASS MIL C/ML       -0.6996       0.2628       0.2508       0.4833
  2. VIABLE BIOMASSMIL C/ML       -1.0099       0.3956       0.3897       0.6575
  5. RES CHLORINE  MG/L            0.0674       0.2346       0.2836       0.3904
  6. TURBIDITY-SIO2MG/L            0.4968       0.1155       0.1314       0.3497
  7. DIS OXYGEN    MG/L            0.4108       0.4661       0.0880       0.6431
 10. AMMONIA       MG/L           -0.1634       0.8047       0.3558       0.8683


 11. NITRATE       MG/L            0.0000       0.0000       0.0000       0.0000
 12. PH            PH              0.4867       0.3927       0.0308       0.3939
 13. TOT ORG CARBON MG/L           0.2524       0.3075       0.1325       0.2588
 14. CONDUCTIVITY  MMMHO/CM        1.3144       0.5839       0.0188       0.5659
 15. TEMPERATURE#1 DEG F           0.7571       0.5917       0.0071       0.7682
 16. HARDNESS      MG/L            0.9152       0.6520       0.185[illegible]       0.6922
 17. SODIUM        MG/L            0.6393       0.7043       0.0234       0.7036
 20. AMBIENT TEMP  DEG F           0.5609       0.6994       0.0060       0.7618
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 2 TO SAMPLE SOURCE 3

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR       UNITS              A0          A1      STANDARD     CORR.      SAMPLE
NO.                                                            ERROR      COEFF.       SIZE

  1. TOTAL BIOMASS MIL C/ML        0.0747      2.5755      0.2910      0.7426          47
  2. VIABLE BIOMASSMIL C/ML        0.1743      0.9792      0.2624      0.1437          48
  5. RES CHLORINE  MG/L            0.2878      0.5855      0.6600      0.6591          55
  6. TURBIDITY-SIO2MG/L            5.3510      0.1294      3.6318      0.2960          63
  7. DIS OXYGEN    MG/L            0.3504      0.9243      1.0272      0.7768          63
 10. AMMONIA       MG/L            0.8076      0.9614      6.6715      0.8950          47
 11. NITRATE       MG/L            0.0000      0.0000      0.0000      0.0000           0
 12. PH            PH              3.6599      0.2872      0.4542      0.6054          63
 13. TOT ORG CARBON MG/L           2.6437      0.7249      2.9859      0.4838          55
 14. CONDUCTIVITY  MMMHO/CM      215.7639      0.8488     33.4419      0.7859          63
 15. TEMPERATURE*1 DEG F           2.7849      0.9614      0.5338      0.9575          63
 16. HARDNESS      MG/L         -280.1863      2.3370    170.4198      0.8351          55
 17. SODIUM        MG/L           15.3843      0.9017      4.3892      0.9159          61
 20. AMBIENT TEMP  DEG F           7.6624      0.8982      0.8972      0.8596          71


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR       UNITS              A0          A1          A2      STANDARD      CORR.
NO.                                                                        ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        0.1139      2.1929      0.6771      0.2908      0.7429
  2. VIABLE BIOMASSMIL C/ML        0.1024      5.2319    -27.1097      0.2582      0.2271
  5. RES CHLORINE  MG/L           -0.3683      1.4901     -0.2172      0.6015      0.7282
  6. TURBIDITY-SIO2MG/L            4.2327      0.2798     -0.0029      3.6186      0.3070
  7. DIS OXYGEN    MG/L           -1.5239      1.4663     -0.0376      1.0223      0.7793
 10. AMMONIA       MG/L           -0.7458      1.7595     -0.0162      6.4574      0.9020
 11. NITRATE       MG/L            0.0000      0.0000      0.0000      0.0000      0.0000
 12. PH            PH             15.7422     -2.9827      0.2186      0.4241      0.6692
 13. TOT ORG CARBON MG/L          -0.0142      1.4642     -0.0465      2.9541      0.5002
 14. CONDUCTIVITY  MMMHO/CM    -6484.1210     11.3550     -0.0041     29.2025      0.8418
 15. TEMPERATURE*1 DEG F         -44.9141      2.2907     -0.0093      0.5330      0.9576
 16. HARDNESS      MG/L          407.8701     -1.9144      0.0050     84.0167      0.9625
 17. SODIUM        MG/L          -93.8915      2.2998     -0.0044      4.3402      0.9178
 20. AMBIENT TEMP  DEG F        -429.6624     12.8660     -0.0818      0.8435      0.8771


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR       UNITS              A0          A1      STANDARD     CORR.
NO.                                                            ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        0.2982      0.8082      0.2081      0.7557
  2. VIABLE BIOMASSMIL C/ML        0.0501      0.5793      0.4050      0.6096
  5. RES CHLORINE  MG/L           -0.1108      0.8666      0.1657      0.8629
  6. TURBIDITY-SIO2MG/L            0.5280      0.2491      0.2099      0.2371
  7. DIS OXYGEN    MG/L           -0.0165      1.0028      0.0545      0.8504
 10. AMMONIA       MG/L            0.0756      0.9101      0.2357      0.9293


 11. NITRATE       MG/L            0.0000      0.0000      0.0000      0.0000
 12. PH            PH              0.4704      0.3349      0.0314      0.6353
 13. TOT ORG CARBON MG/L           0.2448      0.7416      0.1304      0.6461
 14. CONDUCTIVITY  MMMHO/CM        0.4502      0.8575      0.0113      0.7908
 15. TEMPERATURE*1 DEG F           0.0755      0.9594      0.0032      0.9540
 16. HARDNESS      MG/L            0.1401      0.9613      0.1258      0.7602
 17. SODIUM        MG/L            0.2142      0.9024      0.0121      0.9146
 20. AMBIENT TEMP  DEG F           0.2052      0.8906      0.0052      0.8556
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 3 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR        UNITS            A0          A1       STANDARD     CORR.      SAMPLE
NO.                                                            ERROR      COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML        0.1401      0.2948      0.2301      0.5595        81
  2. VIABLE BIOMASSMIL C/ML        0.0789      0.2250      0.1402      0.3509        82
  5. RES CHLORINE  MG/L            0.1965      0.6753      0.3423      0.8532        76
  6. TURBIDITY-SIO2MG/L            9.0953      0.0885      3.2310      0.1500        97
  7. DIS OXYGEN    MG/L            1.2560      0.8644      0.8901      0.8447        98
 10. AMMONIA       MG/L           -0.5591      1.0620      5.4978      0.9199        74
 11. NITRATE       MG/L            0.0000      0.0000
 12. PH            PH              0.8304      0.9010      0.3208      0.8981        98
 13. TOT ORG CARBON MG/L           3.0664      0.5192      1.3800      0.7449        78
 14. CONDUCTIVITY  MMMHO/CM      131.9837      0.9020     15.6259      0.9506        98
 15. TEMPERATURE#1 DEG F           0.1711      0.9957      0.6897      0.9363        96
 16. HARDNESS      MG/L          234.7607      0.0368     69.1733      0.1492        84
 17. SODIUM        MG/L           18.6466      0.8765      4.6809      0.8986        91
 20. AMBIENT TEMP  DEG F           5.8445      0.9206      0.5308      0.9548       107

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR        UNITS            A0          A1          A2       STANDARD     CORR.
NO.                                                                        ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML       -0.0272      0.7485     -0.1887      0.2128      0.6419
  2. VIABLE BIOMASSMIL C/ML        0.0396      0.5230     -0.2494      0.1361      0.4161
  5. RES CHLORINE  MG/L           -0.2546      1.4231     -0.1991      0.2329      0.9349
  6. TURBIDITY-SIO2MG/L           10.4727     -0.3025      0.0195      3.2085      0.1899
  7. DIS OXYGEN    MG/L           -3.6401      2.3235     -0.1025      0.7762      0.8844
 10. AMMONIA       MG/L            2.1283     -0.1897      0.0217      3.2457      0.9728
 11. NITRATE       MG/L            0.0000      0.0000      0.0000
 12. PH            PH              1.3449      0.7472      0.0112      0.3206      0.8982
 13. TOT ORG CARBON MG/L           0.6953      1.0383     -0.0228      1.3072      0.7750
 14. CONDUCTIVITY  MMMHO/CM     1482.9480     -1.2193      0.0008     15.1171      0.9538
 15. TEMPERATURE#1 DEG F           6.0165      0.8315      0.0012      0.6897      0.9363
 16. HARDNESS      MG/L           18.6868      0.9875     -0.0004     35.7406      0.8596
 17. SODIUM        MG/L          171.4216     -1.0727      0.0062      4.6101      0.9018
 20. AMBIENT TEMP  DEG F        -210.5481      6.8493     -0.0406      0.5010      0.9603

LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR        UNITS            A0          A1       STANDARD     CORR.
NO.                                                            ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML       -0.3797      0.6713      0.1818      0.7768
  2. VIABLE BIOMASSMIL C/ML       -0.5608      0.6590      0.3627      0.7092
  5. RES CHLORINE  MG/L           -0.0791      0.9990      0.1324      0.9196
  6. TURBIDITY-SIO2MG/L            0.9073      0.0711      0.1480      0.1183
  7. DIS OXYGEN    MG/L            0.1361      0.8608      0.0475      0.8905
 10. AMMONIA       MG/L           -0.0048      0.8716      0.2734      0.9251


 11. NITRATE       MG/L            0.0000      0.0000
 12. PH            PH              0.1149      0.8736      0.0215      0.8872
 13. TOT ORG CARBON MG/L           0.2004      0.7380      0.0715      0.8440
 14. CONDUCTIVITY  MMMHO/CM        0.3673      0.8825      0.0054      0.9415
 15. TEMPERATURE#1 DEG F           0.0224      0.9875      0.0043      0.9248
 16. HARDNESS      MG/L            1.3804      0.4127      0.1022      0.5965
 17. SODIUM        MG/L            0.2721      0.8751      0.0134      0.8941
 20. AMBIENT TEMP  DEG F           0.1749      0.9063      0.0031      0.9375
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 4 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS              A0          A1       STANDARD     CORR.      SAMPLE
NO.                                                           ERROR      COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML         0.0911      0.5343      0.1281      0.7498         89
  2. VIABLE BIOMASSMIL C/ML         0.0369      0.5051      0.1007      0.5929         89
  5. RES CHLORINE  MG/L             0.2585      0.0041      0.3883      0.0791         84
  6. TURBIDITY-SIO2MG/L             2.4321      0.3472      3.8029      0.2900        107
  7. DIS OXYGEN    MG/L             1.0374      0.7629      0.6553      0.8767        107
 10. AMMONIA       MG/L             0.4835      0.7359      6.8448      0.8358         72
 12. PH            PH               2.4510      0.5987      0.3716      0.7782        107
 13. TOT ORG CARBON MG/L            0.7118      0.4972      1.2986      0.5860         86
 14. CONDUCTIVITY  MMMHO/CM       136.3891      0.9077     32.7114      0.8583        107
 15. TEMPERATURE#1 DEG F            8.1073      0.8885      1.1601      0.8282        105
 16. HARDNESS      MG/L            51.0987      0.7309     85.7176      0.7412         89
 17. SODIUM        MG/L            21.4730      0.8508      4.2222      0.9269        101
 20. AMBIENT TEMP  DEG F            2.3121      0.9667      0.4370      0.9691        118


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS              A0          A1          A2       STANDARD     CORR.
NO.                                                                       ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        -0.0308      1.1515     -0.4489      0.1100      0.8229
  2. VIABLE BIOMASSMIL C/ML         0.0010      1.0368     -0.8410      0.0958      0.6430
  5. RES CHLORINE  MG/L             0.2660     -0.0147      0.0077      0.3882      0.0796
  6. TURBIDITY-SIO2MG/L             1.2510      0.6289     -0.0148      3.7976      0.2944
  7. DIS OXYGEN    MG/L            -1.7095      1.5424     -0.0526      0.6255      0.8884
 10. AMMONIA       MG/L             0.1697      0.8671     -0.0016      6.8307      0.8365
 12. PH            PH               2.9068      0.4646      0.0096      0.3714      0.7784
 13. TOI URG CARBON MG/L            0.0566      0.6602     -0.0092      1.2966      0.5877
 14. CONDUCTIVITY  MMMHO/CM      1232.6410     -0.7736      0.0006     32.5023      0.8603
 15. TEMPERATURE#1 DEG F          108.0780     -1.9256      0.0198      1.1575      0.8291
 16. HARDNESS      MG/L           100.8118      0.3301      0.0008     45.4899      0.7442
 17. SODIUM        MG/L          -161.6827      3.1419     -0.0071      3.9950      0.9348
 20. AMBIENT TEMP  DEG F         -154.3120      5.2545     -0.0293      0.4180      0.9717


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS              A0          A1       STANDARD     CORR.
NO.                                                           ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        -0.2106      0.7604      0.1333      0.8684
  2. VIABLE BIOMASSMIL C/ML        -0.4260      0.7177      0.3087      0.8082
  5. RES CHLORINE  MG/L            -0.7409      0.0840      0.3033      0.5915
  6. TURBIDITY-SIO2MG/L             0.2450      0.4910      0.1543      0.5502
  7. DIS OXYGEN    MG/L             0.0737      0.8642      0.0438      0.8900
 10. AMMONIA       MG/L            -0.1882      0.9704      0.3589      0.8927
 12. PH            PH               0.3071      0.6091      0.0246      0.7764
 13. TOT ORG CARBON MG/L           -0.0380      0.7636      0.1168      0.5953


 14. CONDUCTIVITY  MMMHO/CM         0.3201      0.8989      0.0110      0.8587
 15. TEMPERATURE#1 DEG F            0.2200      0.8818      0.0069      0.8281
 16. HARDNESS      MG/L             0.5401      0.7601      0.0907      0.7226
 17. SODIUM        MG/L             0.2759      0.8719      0.0115      0.9291
 20. AMBIENT TEMP  DEG F            0.0720      0.9610      0.0026      0.9596
```

```
REGRESSION ANALYSIS FOR SEP  3, 1980 TO FEB 28, 1981

FROM SAMPLE SOURCE 5 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS            A0          A1      STANDARD     CORR.      SAMPLE
NO.                                                        ERROR      COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML      0.1666      0.4320      0.3934      0.2268          94
  2. VIABLE BIOMASSMIL C/ML      0.1079      0.2506      0.3941      0.0890          92
  5. RES CHLORINE  MG/L          1.9532      0.0259      1.0713      0.0577          89
  6. TURBIDITY-SIO2MG/L          3.4335      0.1791      1.3696      0.4829         110
  7. DIS OXYGEN    MG/L          0.1704      0.9252      0.7030      0.8770         111
 10. AMMONIA       MG/L         -0.3298      1.4023      2.4786      0.9740          67
 11. NITRATE       MG/L          0.0000      0.0000      0.0000      0.0000           0
 12. PH            PH            1.4046      0.7479      0.2750      0.8554         112
 13. TOT ORG CARBON MG/L         1.7470      0.5023      1.1846      0.5668          88
 14. CONDUCTIVITY  MMMHO/CM    143.0083      0.8906     38.1038      0.8286         112
 16. HARDNESS      MG/L       -220.7516      2.6320    262.0330      0.5677          68
 17. SODIUM        MG/L         20.1280      0.8681      6.5169      0.8301         104


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS            A0          A1          A2    STANDARD     CORR.
NO.                                                                  ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML      0.0757      1.0230     -0.5991      0.3920      0.2405
  2. VIABLE BIOMASSMIL C/ML      0.0659      1.0403     -1.3746      0.3923      0.1296
  5. RES CHLORINE  MG/L          2.0543     -0.6497      0.3356      1.0694      0.0823
  6. TURBIDITY-SIO2MG/L          2.6222      0.3713     -0.0059      1.3364      0.5195
  7. DIS OXYGEN    MG/L          0.0090      0.9768     -0.0039      0.7029      0.8770
 10. AMMONIA       MG/L         -0.5175      1.5220     -0.0029      2.4623      0.9743
 11. NITRATE       MG/L          0.0000      0.0000      0.0000      0.0000      0.0000
 12. PH            PH            4.8220     -0.2802      0.0763      0.2719      0.8589
 13. TOT ORG CARBON MG/L         1.2146      0.7123     -0.0170      1.1793      0.5722
 14. CONDUCTIVITY  MMMHO/CM   3305.6240     -3.9109      0.0018     36.4631      0.8444
 16. HARDNESS      MG/L        786.9370     -6.1214      0.0175    233.4415      0.6798
 17. SODIUM        MG/L         29.5108      0.7481      0.0008      6.5166      0.8301


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS            A0          A1      STANDARD     CORR.
NO.                                                        ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML     -0.2602      0.6149      0.2082      0.7095
  2. VIABLE BIOMASSMIL C/ML     -0.4511      0.5756      0.3203      0.7862
  5. RES CHLORINE  MG/L          0.1410     -0.1023      0.2856      0.3184
  6. TURBIDITY-SIO2MG/L          0.3059      0.4530      0.1085      0.6498
  7. DIS OXYGEN    MG/L         -0.0124      0.9850      0.0581      0.8594
 10. AMMONIA       MG/L          0.0757      0.7944      0.3201      0.8872
 11. NITRATE       MG/L          0.0000      0.0000      0.0000      0.0000
 12. PH            PH            0.1822      0.7559      0.0184      0.8532
 13. TOT ORG CARBON MG/L         0.2019      0.6040      0.1053      0.6440
 14. CONDUCTIVITY  MMMHO/CM      0.3759      0.8793      0.0140      0.7986


 16. HARDNESS      MG/L          0.3415      0.9240      0.2028      0.5875
 17. SODIUM        MG/L          0.2830      0.8703      0.0187      0.8208


EOF..
```

```
LOG-NORMAL DISTRIBUTION:  APR  1, 1979 TO APR 30, 1979

SAMPLE   MONTHLY        ONE             LOG(Y)=F(Z)            CHI        SAMPLE
SOURCE   AVERAGE        SIGMA       SLOPE      INTERCEPT       SQUARE      SIZE

TETRACHLOROETHYLENE

   0       156.7        111.9      0.4879E  0  0.2010E  1      9.0000      20
   1        68.8         40.1      0.4057E  0  0.1713E  1     12.5000      20
   3        31.9         18.5      0.3781E  0  0.1389E  1      8.8000      25
   4        17.0         10.9      0.3791E  0  0.1108E  1      4.8182      22
   5         6.2          7.0      0.3913E  0  0.6049E  0      1.1429      21
   6         6.7          9.3      0.4536E  0  0.5601E  0      4.0000      26

METHYLENE CHLORIDE

   0       228.7        199.9      0.4197E  0  0.2200E  1      1.5000      20
   1        25.5         41.7      0.5803E  0  0.1020E  1      2.5000      20
   3        16.0         21.6      0.5787E  0  0.8609E  0      1.6000      25
   4        13.7         19.9      0.5703E  0  0.7921E  0      0.7273      22
   5        22.2          7.0      0.1608E  0  0.1322E  1      4.4762      21
   6        21.7          6.3      0.1344E  0  0.1318E  1      2.0769      26

1,2-DICHLOROETHYLENE

   0        24.2         78.2      0.7286E  0  0.2363E  0     62.0000      20
   1        41.6        186.2      0.6531E  0  0.1460E  0     70.5000      20
   4        10.1         47.3      0.5002E  0  0.1066E  0     78.4546      22
   5         0.1          0.3      0.1458E -1  0.3182E -2     74.4762      21

CHLOROFORM

   0        31.6         14.9      0.2344E  0  0.1447E  1      2.5000      20
   1        25.1          5.5      0.9458E -1  0.1389E  1      6.5000      20
   3        18.6          5.1      0.1174E  0  0.1255E  1      4.0000      25
   4        17.4          3.7      0.9395E -1  0.1232E  1      3.4545      22
   5         5.6          4.8      0.3020E  0  0.6399E  0      4.9524      21
   6         5.8          3.8      0.2426E  0  0.6939E  0      5.5385      26

1,1,1-TRICHLOROETHANE

   0       175.9        197.8      0.1056E  1  0.1618E  1      3.0000      20
   1        51.0         43.6      0.7834E  0  0.1338E  1     10.0000      20
   3        10.6         10.6      0.6103E  0  0.7298E  0      9.2000      25
   4         6.3          5.2      0.4555E  0  0.6383E  0      4.8182      22
   5         0.8          0.7      0.1049E  0  0.7844E -1     21.6191      21
   6         2.2          7.7      0.3138E  0  0.1007E  0     20.5385      26

BROMODICHLOROMETHANE

   0         2.9          0.9      0.1321E  0  0.4501E  0      5.0000      20
   1         4.0          1.2      0.1599E  0  0.5733E  0     12.5000      20
   3         3.1          1.2      0.1533E  0  0.4642E  0      5.2000      25
   4         2.8          0.6      0.1013E  0  0.4377E  0      0.7273      22
   5         0.7          0.6      0.8816E -1  0.3760E -1     30.1905      21
   6         1.3          1.3      0.1858E  0  0.9150E -1     10.5385      26

EOF..
```

```
LOG-NORMAL DISTRIBUTION:  APR  1, 1979 TO APR 30, 1979

SAMPLE   MONTHLY        ONE           LOG(Y)=F(Z)           CHI      SAMPLE
SOURCE   AVERAGE       SIGMA       SLOPE     INTERCEPT     SQUARE     SIZE

TRICHLOROETHYLENE

  0        74.6         40.3    0.2861E  0  0.1795E  1    6.5000      20
  1        26.5         20.3    0.3141E  0  0.1318E  1    4.0000      20
  3        12.4          8.2    0.3053E  0  0.9986E  0    2.0000      25
  4         8.2          5.2    0.2955E  0  0.8269E  0   11.6364      22
  5         2.2          2.7    0.3206E  0  0.1968E  0   14.9524      21
  6         2.3          3.3    0.3412E  0  0.1820E  0   29.7692      26

DIBROMOCHLOROMETHANE

  0         0.2          0.3    0.8250E -2  0.1845E -2   70.5000      20
  1         1.5          0.4    0.1091E  0  0.1728E  0    6.5000      20
  3         1.4          0.5    0.1107E  0  0.1560E  0    6.4000      25
  4         1.4          0.2    0.6690E -1  0.1565E  0    1.6364      22
  5         0.7          0.2    0.1907E -1  0.5612E -2   65.9048      21
  6         0.9          0.4    0.9349E -1  0.2422E -1   33.6154      26

BROMOFORM

  0         3.4          2.4    0.2745E  0  0.4404E  0    1.5000      20
  1         1.7          0.6    0.1264E  0  0.2218E  0    2.0000      20
  3         5.0         15.3    0.3494E  0  0.3242E  0   29.6000      25
  4         1.9          0.5    0.1114E  0  0.2695E  0    3.9091      22
  5         1.1          0.4    0.7839E -1  0.8151E -1    3.0476      21
  6         1.5          1.7    0.2061E  0  0.1161E  0    4.0000      26

TRIHALOMETHANES

  0        38.1         16.1    0.1801E  0  0.1546E  1    1.5000      20
  1        32.2          6.1    0.8311E -1  0.1501E  1    3.5000      20
  3        28.1         18.3    0.1610E  0  0.1409E  1    5.2000      25
  4        23.6          4.1    0.7798E -1  0.1366E  1    0.2727      22
  5         8.1          5.6    0.2318E  0  0.8410E  0    7.8095      21
  6         9.5          6.5    0.2043E  0  0.9188E  0    8.2308      26

TOTAL HALOCARBONS

  0       698.2        490.1    0.3872E  0  0.2708E  1    2.5000      20
  1       245.6        194.7    0.3286E  0  0.2281E  1    6.5000      20
  3        99.0         49.6    0.2332E  0  0.1940E  1    4.4000      25
  4        78.9         48.7    0.2329E  0  0.1836E  1    6.1818      22
  5        39.5         12.8    0.1279E  0  0.1578E  1    1.6190      21
  6        42.3         24.2    0.1741E  0  0.1584E  1    9.0000      26

EOF..
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 0 TO SAMPLE SOURCE  1

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                 A0         A1      STANDARD     CORR.      SAMPLE
NO.                                                      ERROR      COEFF.      SIZE

 1. TETRACHLOROETHYLENE          13.6005     0.3566    16.1634     0.9293        20
 2. METHYLENE CHLORIDE            6.5537     0.0666    27.7505     0.4299        18
 3. CARBON TETRACHLORIDE          0.0000     0.0000     0.0000     0.0000         0
 4. 1,2-DICHLOROETHYLENE          0.0000     0.0000     0.0000     0.0000         0
 5. CHLOROFORM                   22.7212     0.0381     5.6183     0.2126        20
 6. 1,1,1-TRICHLOROETHANE        24.2778     0.1816    22.0835     0.8678        16
 7. BROMODICHLOROMETHANE          2.6789     0.4420     1.1396     0.4220        19
 8. TRICHLOROETHYLENE            -1.5580     0.3784    12.9699     0.7696        20
 9. DIBROMOCHLOROMETHANE          1.6950     0.1010     0.3407     0.6398        10
10. BROMOFORM                     1.6768    -0.0001     0.6193     0.0972        20
11. TRIHALOMETHANES              29.0771     0.0478     6.4470     0.2298        20
12. TOTAL HALOCARBONS            76.1989     0.1969    66.6918     0.7930        20

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                 A0         A1         A2       STANDARD     CORR.
NO.                                                                  ERROR      COEFF.

 1. TETRACHLOROETHYLENE          13.6598     0.3551     0.0000    16.1634     0.9293
 2. METHYLENE CHLORIDE           21.8851    -0.0545     0.0001    26.5809     0.5021
 3. CARBON TETRACHLORIDE          0.0000     0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE          0.0000     0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                   29.8367    -0.4586     0.0071     5.3893     0.3485
 6. 1,1,1-TRICHLOROETHANE        16.3032     0.2868    -0.0002    21.1365     0.8796
 7. BROMODICHLOROMETHANE          3.3421     0.0080     0.0645     1.1380     0.4248
 8. TRICHLOROETHYLENE            11.6621    -0.1151     0.0033    12.0919     0.8035
 9. DIBROMOCHLOROMETHANE          0.1379     6.1002    -4.3886     0.2733     0.7874
10. BROMOFORM                     1.5239     0.0892    -0.0087     0.6164     0.1369
11. TRIHALOMETHANES              43.6637    -0.7292     0.0089     6.1011     0.3895
12. TOTAL HALOCARBONS            37.9438     0.3453    -0.0000    63.2845     0.8160

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                 A0         A1      STANDARD     CORR.
NO.                                                      ERROR      COEFF.

 1. TETRACHLOROETHYLENE           0.0942     0.8053     0.1531     0.9491
 2. METHYLENE CHLORIDE           -0.8254     0.8274     0.4444     0.7248
 3. CARBON TETRACHLORIDE          0.0000     0.0000     0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE          0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                    1.3809    -0.0095     0.1005     0.0870
 6. 1,1,1-TRICHLOROETHANE        -0.0243     0.7934     0.1824     0.9124
 7. BROMODICHLOROMETHANE          0.3875     0.4167     0.1514     0.3475
 8. TRICHLOROETHYLENE            -0.3515     0.9312     0.1586     0.8783
 9. DIBROMOCHLOROMETHANE          0.2642     0.0858     0.0799     0.6638
10. BROMOFORM                     0.1411     0.1128     0.1780     0.2021
11. TRIHALOMETHANES               1.4463     0.0220     0.0921     0.1095
12. TOTAL HALOCARBONS             0.3556     0.6970     0.1648     0.8560
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 3

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                  A0          A1       STANDARD    CORR.      SAMPLE
NO.                                                        ERROR      COEFF.      SIZE

 1. TETRACHLOROETHYLENE            7.3943      0.3142     11.5381     0.7604        23
 2. METHYLENE CHLORIDE             4.9045      0.4017     14.7889     0.7533        19
 3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000     0.0000         0
 4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000     0.0000         0
 5. CHLOROFORM                     7.4191      0.4587      4.2044     0.5433        23
 6. 1,1,1-TRICHLOROETHANE          3.8890      0.1897      3.9397     0.8966        18
 7. BROMODICHLOROMETHANE           0.6949      0.6354      0.9580     0.6017        22
 8. TRICHLOROETHYLENE              4.0121      0.2957      3.6229     0.8484        23
 9. DIBROMOCHLOROMETHANE           1.3025      0.1721      0.4386     0.1904        23
10. BROMOFORM                     25.4870    -11.5563     14.5494     0.4038        22
11. TRIHALOMETHANES               20.6090     -0.0125     18.7022     0.0252        23
12. TOTAL HALOCARBONS             28.0748      0.3366     32.1783     0.7590        23

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                  A0          A1          A2       STANDARD    CORR.
NO.                                                                    ERROR      COEFF.

 1. TETRACHLOROETHYLENE            3.1346      0.5008     -0.0013     11.2477     0.7741
 2. METHYLENE CHLORIDE             8.5157      0.0820      0.0023     14.2838     0.7723
 3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000      0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000      0.0000     0.0000
 5. CHLOROFORM                    20.1573     -0.6449      0.0225      4.1337     0.5645
 6. 1,1,1-TRICHLOROETHANE          2.9632      0.2321     -0.0003      3.9082     0.8983
 7. BROMODICHLOROMETHANE          -0.1707      1.1084     -0.0594      0.9498     0.6107
 8. TRICHLOROETHYLENE              1.3669      0.4881     -0.0022      3.3210     0.8744
 9. DIBROMOCHLOROMETHANE           1.6485     -0.3114      0.1574      0.4370     0.2075
10. BROMOFORM                     75.3304    -71.0035     16.0699     12.3877     0.6271
11. TRIHALOMETHANES               27.1836      0.0825     -0.0015     18.7020     0.0255
12. TOTAL HALOCARBONS             45.2072      0.0991      0.0006     31.6906     0.7674

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                  A0          A1       STANDARD    CORR.
NO.                                                        ERROR      COEFF.

 1. TETRACHLOROETHYLENE           -0.1302      0.8599      0.1804     0.9202
 2. METHYLENE CHLORIDE            -0.1847      0.9239      0.3355     0.8547
 3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000     0.0000
 4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000     0.0000
 5. CHLOROFORM                     0.4746      0.5674      0.0960     0.5537
 6. 1,1,1-TRICHLOROETHANE         -0.0263      0.6873      0.1113     0.9330
 7. BROMODICHLOROMETHANE          -0.0062      0.8430      0.0919     0.8134
 8. TRICHLOROETHYLENE             -0.0459      0.7890      0.1550     0.8789
 9. DIBROMOCHLOROMETHANE           0.1625      0.1180      0.0951     0.1550
10. BROMOFORM                      0.5537     -0.9368      0.3257     0.7428
11. TRIHALOMETHANES                0.9563      0.3042      0.1639     0.2765
12. TOTAL HALOCARBONS              0.5666      0.6129      0.1531     0.8094
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1. 1979 TO APR 30. 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL       COMPOUND                A0         A1      STANDARD    CORR.      SAMPLE
NO.                                                   ERROR      COEFF.      SIZE

  . TETRACHLOROETHYLENE         2.1575     0.1896     4.9222     0.8537       22
  . METHYLENE CHLORIDE          4.8291     0.3698    13.8972     0.7492       19
    CARBON TETRACHLORIDE        0.0600     0.0000     0.0000     0.0000        0
 4. 1.2-DICHLOROETHYLENE        0.0000     0.0000     0.0000     0.0000        0
 5. CHLOROFORM                  4.3469     0.5223     2.2221     0.7960       22
 6. 1.1.1-TRICHLOROETHANE       3.0052     0.0843     2.1206     0.8776       18
 7. BROMODICHLOROMETHANE        1.2289     0.4262     0.2858     0.8815       21
 8. TRICHLOROETHYLENE           1.8771     0.2225     1.8605     0.9184       22
 9. DIBROMOCHLOROMETHANE        1.2644     0.1581     0.1412     0.5128       22
10. BROMOFORM                   1.3432     0.3886     0.2975     0.6800       21
11. TRIHALOMETHANES             7.6276     0.4993     2.6491     0.7708       22
12. TOTAL HALOCARBONS          40.4344     0.1804    44.4580     0.4024       22

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL       COMPOUND                A0         A1         A2      STANDARD     CORR.
NO.                                                               ERROR      COEFF.

 1. TETRACHLOROETHYLENE         0.1493     0.2784    -0.0006     4.7600     0.8640
 2. METHYLENE CHLORIDE          7.4123     0.1411     0.0016    13.6242     0.7605
 3. CARBON TETRACHLORIDE        0.0000     0.0000     0.0000     0.0000     0.0000
 4. 1.2-DICHLOROETHYLENE        0.0000     0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                 -1.7281     1.0281    -0.0100     2.2056     0.7994
 6. 1.1.1-TRICHLOROETHANE       2.0724     0.1270    -0.0003     2.0606     0.8848
 7. BROMODICHLOROMETHANE        1.1148     0.4888    -0.0079     0.2853     0.8819
 8. TRICHLOROETHYLENE           0.8902     0.2911    -0.0008     1.7920     0.9245
 9. DIBROMOCHLOROMETHANE        1.4691    -0.1285     0.0933     0.1394     0.5301
10. BROMOFORM                   1.0687     0.7161    -0.0882     0.2945     0.6880
11. TRIHALOMETHANES             1.2309     0.9186    -0.0066     2.6336     0.7739
12. TOTAL HALOCARBONS           7.8110     0.6401    -0.0011    43.1337     0.4594

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL       COMPOUND                A0         A1      STANDARD    CORR.
NO.                                                   ERROR      COEFF.

 1. TETRACHLOROETHYLENE        -0.3489     0.8286     0.1434     0.9440
 2. METHYLENE CHLORIDE         -0.2261     0.9287     0.3523     0.8365
 3. CARBON TETRACHLORIDE        0.0000     0.0000     0.0000     0.0000
 4. 1.2-DICHLOROETHYLENE        0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                  0.1779     0.7593     0.0557     0.8078
 6. 1.1.1-TRICHLOROETHANE      -0.0749     0.5614     0.1050     0.9182
 7. BROMODICHLOROMETHANE        0.1619     0.5123     0.0425     0.8875
 8. TRICHLOROETHYLENE          -0.3121     0.8484     0.1107     0.9315
 9. DIBROMOCHLOROMETHANE        0.1534     0.1324     0.0420     0.4599
10. BROMOFORM                   0.2303     0.3125     0.0653     0.6595
11. TRIHALOMETHANES             0.3428     0.6841     0.0487     0.7878
12. TOTAL HALOCARBONS           0.5483     0.5721     0.1684     0.7441
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL       COMPOUND                      A0          A1       STANDARD     CORR.      SAMPLE
NO.                                                            ERROR      COEFF.      SIZE

  1. TETRACHLOROETHYLENE            2.3298      0.0351      5.6711      0.3073        21
  2. METHYLENE CHLORIDE            23.8529     -0.0415      5.4097      0.3254        19
  3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000      0.0000         0
  4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000      0.0000         0
  5. CHLOROFORM                     5.2824     -0.0343      2.5104      0.3271        21
  6. 1,1,1-TRICHLOROETHANE          1.2286     -0.0018      0.5854      0.4125        16
  7. BROMODICHLOROMETHANE           0.7039      0.0161      0.3117      0.2827        14
  8. TRICHLOROETHYLENE              1.2702      0.0146      1.8925      0.3268        21
  9. DIBROMOCHLOROMETHANE           0.6947      0.0046      0.1518      0.4891        21
 10. BROMOFORM                      0.6033      0.3422      0.5850      0.5738        21
 11. TRIHALOMETHANES                7.5824     -0.0218      2.9221      0.4809        21
 12. TOTAL HALOCARBONS             38.6494     -0.0072     10.7663      0.2533        21

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL       COMPOUND                      A0          A1          A2       STANDARD     CORR.
NO.                                                                        ERROR      COEFF.

  1. TETRACHLOROETHYLENE            0.0772      0.1365     -0.0007      5.4863      0.3905
  2. METHYLENE CHLORIDE            25.4473     -0.1906      0.0011      5.0891      0.4569
  3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                   -12.2740      1.4175     -0.0286      2.3878      0.4383
  6. 1,1,1-TRICHLOROETHANE          1.2961     -0.0047      0.0000      0.5845      0.4158
  7. BROMODICHLOROMETHANE           0.4756      0.1456     -0.0163      0.3090      0.3089
  8. TRICHLOROETHYLENE              0.7120      0.0540     -0.0004      1.8704      0.3572
  9. DIBROMOCHLOROMETHANE           0.5764      0.1573     -0.0467      0.1515      0.4916
 10. BROMOFORM                      0.3359      0.6638     -0.0872      0.5834      0.5770
 11. TRIHALOMETHANES              -16.5548      1.5343     -0.0241      2.7424      0.5683
 12. TOTAL HALOCARBONS             27.7277      0.1507     -0.0004     10.1197      0.4161

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL       COMPOUND                      A0          A1       STANDARD     CORR.
NO.                                                            ERROR      COEFF.

  1. TETRACHLOROETHYLENE           -0.5488      0.6233      0.2449      0.8468
  2. METHYLENE CHLORIDE             1.4126     -0.0685      0.1243      0.3108
  3. CARBON TETRACHLORIDE           0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE           0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                     0.3107      0.1958      0.2523      0.4945
  6. 1,1,1-TRICHLOROETHANE          0.1569     -0.1316      0.3670      0.4946
  7. BROMODICHLOROMETHANE          -0.1937      0.0652      0.2059      0.4033
  8. TRICHLOROETHYLENE             -0.2489      0.2660      0.2435      0.7374
  9. DIBROMOCHLOROMETHANE          -0.1753      0.0528      0.1075      0.4987
 10. BROMOFORM                     -0.0823      0.4868      0.2196      0.6509
 11. TRIHALOMETHANES                0.5562      0.1662      0.1676      0.5983
 12. TOTAL HALOCARBONS              1.5969     -0.0187      0.1103      0.3838
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                  A0          A1       STANDARD     CORR.      SAMPLE
NO.                                                       ERROR        COEFF.      SIZE

  1. TETRACHLOROETHYLENE          2.4539      0.0128      3.3844      0.6793         23
  2. METHYLENE CHLORIDE          22.8559     -0.0254      4.2509      0.2716         20
  3. CARBON TETRACHLORIDE         0.0000      0.0000      0.0000      0.0000          0
  4. 1,2-DICHLOROETHYLENE         0.0000      0.0000      0.0000      0.0000          0
  5. CHLOROFORM                   4.8694     -0.0212      1.8337      0.5440         23
  6. 1,1,1-TRICHLOROETHANE        1.0139     -0.0025      0.5193      0.9137         17
  7. BROMODICHLOROMETHANE         0.1980      0.1994      0.3613      0.6813         22
  8. TRICHLOROETHYLENE            0.9077      0.0069      0.9204      0.7567         23
  9. DIBROMOCHLOROMETHANE         0.7209      0.0503      0.1647      0.3415         22
 10. BROMOFORM                    0.2122      0.5198      0.3925      0.7123         22
 11. TRIHALOMETHANES              7.1661      0.0012      2.3460      0.6259         23
 12. TOTAL HALOCARBONS           35.0175     -0.0040      7.8541      0.6634         23

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                  A0          A1          A2       STANDARD     CORR.
NO.                                                                    ERROR       COEFF.

  1. TETRACHLOROETHYLENE          1.0169      0.0407     -0.0002      3.3625      0.6844
  2. METHYLENE CHLORIDE          23.6080     -0.0964      0.0005      4.1643      0.3333
  3. CARBON TETRACHLORIDE         0.0000      0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE         0.0000      0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                   0.9557      0.3179     -0.0069      1.8185      0.5546
  6. 1,1,1-TRICHLOROETHANE        1.0638     -0.0046      0.0000      0.5187      0.9139
  7. BROMODICHLOROMETHANE         0.4087      0.0843      0.0145      0.3600      0.6841
  8. TRICHLOROETHYLENE            0.5796      0.0308     -0.0003      0.9027      0.7674
  9. DIBROMOCHLOROMETHANE         0.6780      0.1504     -0.0195      0.1646      0.3425
 10. BROMOFORM                    0.7541     -0.1266      0.1747      0.3836      0.7276
 11. TRIHALOMETHANES             -1.0974      0.6051     -0.0096      2.3056      0.6423
 12. TOTAL HALOCARBONS           28.9408      0.0843     -0.0002      7.5746      0.6923

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                  A0          A1       STANDARD     CORR.
NO.                                                        ERROR       COEFF.

  1. TETRACHLOROETHYLENE         -0.2760      0.3906      0.2789      0.8554
  2. METHYLENE CHLORIDE           1.3518     -0.0141      0.0852      0.1008
  3. CARBON TETRACHLORIDE         0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE         0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                   0.6842     -0.0622      0.1958      0.5946
  6. 1,1,1-TRICHLOROETHANE        0.0186     -0.1324      0.3869      0.7978
  7. BROMODICHLOROMETHANE        -0.4015      0.6254      0.1513      0.7340
  8. TRICHLOROETHYLENE           -0.2363      0.1609      0.1869      0.8896
  9. DIBROMOCHLOROMETHANE        -0.0956      0.1328      0.0754      0.4206
 10. BROMOFORM                   -0.1225      0.5909      0.1781      0.6805
 11. TRIHALOMETHANES              0.2215      0.4091      0.1792      0.6083
 12. TOTAL HALOCARBONS            1.5376     -0.0061      0.0928      0.6988
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1. 1979 TO APR 30. 1979

FROM SAMPLE SOURCE 3 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                A0         A1      STANDARD     CORR.      SAMPLE
NO.                                                    ERROR       COEFF.      SIZE

 1. TETRACHLOROETHYLENE         -0.1740     0.5701     2.5754     0.9710        24
 2. METHYLENE CHLORIDE           0.0235     0.8289     6.9791     0.9369        21
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000         0
 4. 1.2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000         0
 5. CHLOROFORM                  10.0151     0.3791     3.1964     0.5117        24
 6. 1.1.1-TRICHLOROETHANE        1.1112     0.4550     0.8798     0.9800        18
 7. BROMODICHLOROMETHANE         0.7811     0.6911     0.3158     0.8645        23
 8. TRICHLOROETHYLENE            0.7034     0.5791     1.6494     0.9446        24
 9. DIBROMOCHLOROMETHANE         0.7761     0.4809     0.1690     0.6903        24
10. BROMOFORM                    1.9460    -0.0047     0.4524     0.2334        23
11. TRIHALOMETHANES             23.1097    -0.0009     4.2578     0.0039        24
12. TOTAL HALOCARBONS           48.4151     0.2921    44.4632     0.3176        24

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                A0         A1         A2       STANDARD     CORR.
NO.                                                                ERROR       COEFF.

 1. TETRACHLOROETHYLENE          0.8220     0.4697     0.0016     2.5020     0.9726
 2. METHYLENE CHLORIDE           1.6947     0.6137     0.0028     6.7243     0.9416
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000     0.0000
 4. 1.2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                 -12.5998     2.7862    -0.0597     2.5766     0.7214
 6. 1.1.1-TRICHLOROETHANE        0.2686     0.5948    -0.0043     0.8311     0.9822
 7. BROMODICHLOROMETHANE         0.9682     0.5585     0.0220     0.3151     0.8652
 8. TRICHLOROETHYLENE            0.2296     0.6608    -0.0025     1.6333     0.9457
 9. DIBROMOCHLOROMETHANE         0.8287     0.3636     0.0538     0.1686     0.6918
10. BROMOFORM                    0.5046     0.8131    -0.0102     0.3806     0.5752
11. TRIHALOMETHANES              4.6842     0.9515    -0.0073     3.2003     0.6596
12. TOTAL HALOCARBONS           48.9806     0.2800     0.0001    44.4628     0.3176

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                A0         A1      STANDARD     CORR.
NO.                                                    ERROR       COEFF.

 1. TETRACHLOROETHYLENE         -0.1852     0.9555     0.0497     0.9932
 2. METHYLENE CHLORIDE          -0.0137     0.9385     0.1369     0.9747
 3. CARBON TETRACHLORIDE         0.0000     0.0000     0.0000     0.0000
 4. 1.2-DICHLOROETHYLENE         0.0000     0.0000     0.0000     0.0000
 5. CHLOROFORM                   0.6163     0.4828     0.0774     0.5904
 6. 1.1.1-TRICHLOROETHANE       -0.0592     0.8220     0.0442     0.9860
 7. BROMODICHLOROMETHANE         0.1524     0.6344     0.0585     0.8160
 8. TRICHLOROETHYLENE           -0.0799     0.8955     0.0611     0.9793
 9. DIBROMOCHLOROMETHANE         0.1198     0.2903     0.0592     0.6786
10. BROMOFORM                    0.2716    -0.0080     0.1189     0.0395
11. TRIHALOMETHANES              1.2038     0.1084     0.0802     0.2298
12. TOTAL HALOCARBONS            0.6542     0.6061     0.1801     0.6737
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 4 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                A0          A1       STANDARD      CORR.        SAMPLE
NO.                                                      ERROR       COEFF.         SIZE

  1. TETRACHLOROETHYLENE        -1.4173      0.4476      4.7209      0.7079          23
  2. METHYLENE CHLORIDE         23.0903     -0.0917      6.1572      0.2948          20
  3. CARBON TETRACHLORIDE        0.0000      0.0000      0.0000      0.0000           0
  4. 1,2-DICHLOROETHYLENE        0.0000      0.0000      0.0000      0.0000           0
  5. CHLOROFORM                  1.6930      0.2243      4.4280      0.1955          23
  6. 1,1,1-TRICHLOROETHANE       1.0962      0.0010      0.5894      0.3985          16
  7. BROMODICHLOROMETHANE        1.3650     -0.1534      0.4636      0.2442          16
  8. TRICHLOROETHYLENE           0.2046      0.2401      2.1981      0.4885          23
  9. DIBROMOCHLOROMETHANE        1.1586     -0.2919      0.1686      0.4608          23
 10. BROMOFORM                   0.6796      0.2780      0.5941      0.5148          22
 11. TRIHALOMETHANES             5.4341      0.1171      5.1635      0.1185          23
 12. TOTAL HALOCARBONS          37.6778      0.0159     12.1117      0.1026          23

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                A0          A1          A2       STANDARD      CORR.
NO.                                                                   ERROR       COEFF.

  1. TETRACHLOROETHYLENE         0.4830      0.1513      0.0077      4.5678      0.7300
  2. METHYLENE CHLORIDE         25.8769     -0.5131      0.0059      5.3525      0.5568
  3. CARBON TETRACHLORIDE        0.0000      0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE        0.0000      0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                 21.1113     -2.1065      0.0666      4.3677      0.2535
  6. 1,1,1-TRICHLOROETHANE       1.8619     -0.2263      0.0134      0.5549      0.5045
  7. BROMODICHLOROMETHANE        2.0666     -0.6914      0.0964      0.4606      0.2682
  8. TRICHLOROETHYLENE          -0.1530      0.3343     -0.0044      2.1927      0.4924
  9. DIBROMOCHLOROMETHANE        2.9389     -3.1178      1.0725      0.1484      0.6243
 10. BROMOFORM                   2.4070     -1.7719      0.5657      0.5762      0.5556
 11. TRIHALOMETHANES            14.4303     -0.6874      0.0174      5.1538      0.1333
 12. TOTAL HALOCARBONS          35.3212      0.0678     -0.0002     12.0843      0.1225

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                A0          A1       STANDARD      CORR.
NO.                                                      ERROR       COEFF.

  1. TETRACHLOROETHYLENE        -0.3851      0.8834      0.2094      0.8906
  2. METHYLENE CHLORIDE          1.4199     -0.1246      0.1359      0.4915
  3. CARBON TETRACHLORIDE        0.0000      0.0000      0.0000      0.0000
  4. 1,2-DICHLOROETHYLENE        0.0000      0.0000      0.0000      0.0000
  5. CHLOROFORM                 -0.0013      0.5213      0.2974      0.3233
  6. 1,1,1-TRICHLOROETHANE       0.0017     -0.0789      0.3705      0.4797
  7. BROMODICHLOROMETHANE        0.0573     -0.3469      0.2361      0.2242
  8. TRICHLOROETHYLENE          -0.3192      0.5910      0.2694      0.6918
  9. DIBROMOCHLOROMETHANE       -0.0714     -0.4978      0.1098      0.4845
 10. BROMOFORM                  -0.0404      0.2616      0.2294      0.5790
 11. TRIHALOMETHANES             0.3524      0.3660      0.2157      0.3697
 12. TOTAL HALOCARBONS           1.5146      0.0316      0.1208      0.2391
```

```
GAS CHROMATOGRAPH REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 5 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CAL        COMPOUND                A0         A1       STANDARD     CORR.      SAMPLE
NO.                                                      ERROR      COEFF.      SIZE

  1. TETRACHLOROETHYLENE         1.7899     0.5418      5.6570     0.5618        24
  2. METHYLENE CHLORIDE         11.9355     0.4896      4.3069     0.6155        24
  3. CARBON TETRACHLORIDE        0.0000     0.0000      0.0000     0.0000         0
  4. 1,2-DICHLOROETHYLENE        0.0000     0.0000      0.0000     0.0000         0
  5. CHLOROFORM                  3.1761     0.2719      2.4711     0.5199        23
  6. 1,1,1-TRICHLOROETHANE      -2.1733     2.7576      1.1714     0.9920        17
  7. BROMODICHLOROMETHANE       -0.0094     1.2046      0.6843     0.8907        17
  8. TRICHLOROETHYLENE           0.5514     0.5983      2.6570     0.5026        24
  9. DIBROMOCHLOROMETHANE       -0.0150     1.1604      0.2435     0.8287        23
 10. BROMOFORM                  -0.0690     0.9478      0.5426     0.9503        23
 11. TRIHALOMETHANES             3.6805     0.5823      5.9174     0.4695        24
 12. TOTAL HALOCARBONS          -2.7754     1.0822     18.9517     0.5905        24

PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CAL        COMPOUND                A0         A1          A2       STANDARD     CORR.
NO.                                                                  ERROR      COEFF.

  1. TETRACHLOROETHYLENE        -0.6687     1.3797     -0.0312      5.4255     0.6087
  2. METHYLENE CHLORIDE         25.1221    -0.8766      0.0321      3.9838     0.6845
  3. CARBON TETRACHLORIDE        0.0000     0.0000      0.0000      0.0000     0.0000
  4. 1,2-DICHLOROETHYLENE        0.0000     0.0000      0.0000      0.0000     0.0000
  5. CHLOROFORM                 -0.2619     1.3699     -0.0516      1.9371     0.7427
  6. 1,1,1-TRICHLOROETHANE       0.0464     0.4996      0.1443      0.2612     0.9996
  7. BROMODICHLOROMETHANE        1.2473    -0.6322      0.3409      0.4140     0.9614
  8. TRICHLOROETHYLENE          -2.3631     3.3160     -0.2744      2.1292     0.7211
  9. DIBROMOCHLOROMETHANE        1.2867    -1.4878      1.1115      0.1437     0.9439
 10. BROMOFORM                   0.8597     0.0158      0.0968      0.3804     0.9759
 11. TRIHALOMETHANES            -5.6317     2.5382     -0.0724      5.1823     0.6341
 12. TOTAL HALOCARBONS         -36.6580     2.6330     -0.0159     18.6339     0.6086

LOGARITHMIC CURVE FIT RESULTS (LOG[Y]=A0 +A1*LOG[X])

CAL        COMPOUND                A0         A1       STANDARD     CORR.
NO.                                                      ERROR      COEFF.

  1. TETRACHLOROETHYLENE        -0.0248     0.8387      0.2390     0.8399
  2. METHYLENE CHLORIDE          0.8501     0.3746      0.0821     0.5646
  3. CARBON TETRACHLORIDE        0.0000     0.0000      0.0000     0.0000
  4. 1,2-DICHLOROETHYLENE        0.0000     0.0000      0.0000     0.0000
  5. CHLOROFORM                  0.2946     0.4982      0.1641     0.7743
  6. 1,1,1-TRICHLOROETHANE      -0.1230     1.1735      0.1877     0.9647
  7. BROMODICHLOROMETHANE        0.0607     0.4900      0.2092     0.6063
  8. TRICHLOROETHYLENE          -0.0823     0.7722      0.2290     0.8537
  9. DIBROMOCHLOROMETHANE        0.0045     0.5633      0.0981     0.6424
 10. BROMOFORM                  -0.0203     0.7449      0.1513     0.8521
 11. TRIHALOMETHANES             0.2755     0.6766      0.1885     0.6937
 12. TOTAL HALOCARBONS           0.1189     0.9141      0.1218     0.7196
```

```
LOG-NORMAL DISTRIBUTION:  APR  1, 1979 TO APR 30, 1979

SAMPLE   MONTHLY        ONE           LOG(Y)=F(Z)            CHI      SAMPLE
SOURCE   AVERAGE       SIGMA       SLOPE     INTERCEPT      SQUARE     SIZE

TOTAL BIOMASS

   0        30.6         3.8      0.5677E -1  0.1482E  1   23.3750      16
   1        14.3         3.4      0.1188E  0  0.1141E  1    2.0000      25
   3         5.6         3.1      0.1880E  0  0.6986E  0    7.3793      29
   4         2.4         0.6      0.9200E -1  0.3665E  0   23.6154      26
   5         2.7         0.9      0.9868E -1  0.4171E  0    8.8000      25
   6         2.5         0.7      0.9035E -1  0.3877E  0   23.9310      29

VIABLE BIOMASS

   0         5.9         6.4      0.7849E  0  0.4564E  0    8.8333      12
   1         3.4         1.8      0.2029E  0  0.4880E  0    3.6000      25
   3         1.6         2.1      0.5040E  0 -0.1115E  0    3.4286      28
   4         1.5         4.3      0.8480E  0 -0.8321E  0    4.3636      22
   5         0.9         2.7      0.5299E  0 -0.6716E  0   14.3333      24
   6         0.4         0.8      0.4038E  0 -0.6624E  0    3.3333      30

RES CHLORINE

   0         0.1         0.0      0.8260E -3 -0.1000E  1   32.0000       8
   1        10.2         4.7      0.1544E  0  0.9793E  0    9.5714      14
   3         6.0         3.1      0.4940E  0  0.6594E  0   15.2857      14
   4         5.2         0.9      0.8556E -1  0.7045E  0    2.1667      12
   5         1.1         2.3      0.4824E  0 -0.3690E  0   35.0769      13
   6         2.3         0.8      0.3725E  0  0.2819E  0   16.6667      15

TURBIDITY-SI02

   0        49.3        15.3      0.3475E  0  0.1632E  1   49.8261      23
   1        21.2        11.0      0.2263E  0  0.1274E  1    2.0769      26
   3        12.3         4.2      0.2505E  0  0.1044E  1   29.0000      30
   4        13.7         6.1      0.2960E  0  0.1065E  1   19.8519      27
   5         4.3         3.1      0.2128E  0  0.5766E  0    9.0000      26
   6         3.1         1.0      0.1423E  0  0.4670E  0    3.3333      30

TOT ORG CARBON

   0        54.1        17.1      0.1275E  0  0.1714E  1   11.5000      20
   1        14.6         5.9      0.1394E  0  0.1140E  1    6.0000      24
   3        13.2         7.0      0.1858E  0  0.1081E  1    2.8000      25
   4        11.9         6.4      0.1689E  0  0.1038E  1    2.4348      23
   5         5.1         4.9      0.4773E  0  0.5051E  0    0.5833      24
   6         5.1         5.1      0.4514E  0  0.5136E  0    0.5385      26

EOF..
```

```
LOG-NORMAL DISTRIBUTION:  APR  1, 1979 TO APR 30, 1979

SAMPLE   MONTHLY        ONE           LOG(Y)=F(Z)           CHI      SAMPLE
SOURCE   AVERAGE       SIGMA       SLOPE     INTERCEPT      SQUARE     SIZE

AMMONIA

   0        27.9         4.4    0.6925E -1  0.1440E  1     2.8696      23
   1        19.2         4.3    0.9988E -1  0.1273E  1     7.4615      26
   3        19.9         4.7    0.1104E  0  0.1285E  1     3.6667      30
   4        19.4         5.4    0.1340E  0  0.1269E  1     8.0000      25
   5        17.5         5.0    0.1346E  0  0.1225E  1     9.6000      25
   6        17.1         4.8    0.1295E  0  0.1214E  1     3.6667      30

PH

   0         7.2         0.3    0.1722E -1  0.8563E  0     6.3478      23
   1         7.0         0.3    0.1629F -1  0.8469E  0     4.7692      26
   3         7.3         0.3    0.1847E -1  0.8649E  0     3.6667      30
   4         7.6         0.2    0.1173E -1  0.8794E  0     6.5185      27
   5         7.4         0.3    0.1565E -1  0.8699E  0     4.7692      26
   6         7.2         0.2    0.1451E -1  0.8583E  0     4.3333      30

CONDUCTIVITY

   0      1471.4        73.5    0.2215E -1  0.3167E  1     2.4348      23
   1      1466.0        69.2    0.2035E -1  0.3166E  1     5.9231      26
   3      1525.4        49.6    0.1445E -1  0.3183E  1     8.3333      30
   4      1537.3        64.8    0.1820E -1  0.3186E  1     3.5556      27
   5      1541.8        65.5    0.1845E -1  0.3188E  1     2.8462      26
   6      1562.5        73.0    0.2019E -1  0.3193E  1     6.3333      30

HARDNESS

   0        36.2        16.9    0.2186E  0  0.1512E  1     0.8750      16
   1       425.5       264.0    0.2301E  0  0.2565E  1     2.5000      20
   3       279.5        84.7    0.1231E  0  0.2429E  1     0.1667      24
   4       300.4        94.1    0.1317E  0  0.2458E  1     2.5714      21
   5       218.6        73.3    0.1251E  0  0.2321E  1     2.0000      20
   6       307.0        85.4    0.1182E  0  0.2471E  1     6.8333      24

EOF..
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 0 TO SAMPLE SOURCE 1

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR      UNITS            A0           A1      STANDARD      CORR.      SAMPLE
NO.                                                         ERROR        COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML        6.5642       0.2642      3.8829      0.2582         14
  2. VIABLE BIOMASSMIL C/ML        4.8504      -0.0833      2.1870      0.4379         10
  5. RES CHLORINE  MG/L            8.7811       0.0000      0.7818      0.8794          8
  6. TURBIDITY-SIO2MG/L            9.9550       0.2480     10.9109      0.3429         21
  9. TOT ORG CARBONMG/L           10.7391       0.0842      5.9630      0.2527         20
 10. AMMONIA       MG/L            9.0887       0.3858      4.2156      0.3723         21
 12. PH            PH              3.5481       0.4847      0.2403      0.4982         21
 13. TOT ORG CARBON MG/L           0.0000       0.0000      0.0000      0.0000          0
 14. CONDUCTIVITY  MMMHO/CM     1050.6140       0.2880     47.9734      0.4256         21
 16. HARDNESS      MG/L           77.2443       9.2559    228.1157      0.5690         14
 17. SODIUM        MG/L           25.0089       0.7623      9.7510      0.8765         21


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR      UNITS            A0           A1           A2       STANDARD      CORR.
NO.                                                                       ERROR        COEFF.

  1. TOTAL BIOMASS MIL C/ML      130.5209      -8.4044       0.1487      3.6378       0.4251
  2. VIABLE BIOMASSMIL C/ML        4.2134       0.1228      -0.0078      2.1550       0.4639
  5. RES CHLORINE  MG/L            8.7811       0.0000       0.0000      0.7818       0.8794
  6. TURBIDITY-SIO2MG/L            8.4333       0.3351      -0.0010     10.8997       0.3455
  9. TOT ORG CARBONMG/L            7.7837       0.1887      -0.0008      5.9593       0.2549
 10. AMMONIA       MG/L           -8.2391       1.6550      -0.0227      4.1856       0.3884
 12. PH            PH            -30.8204      10.0400      -0.6631      0.2261       0.5780
 13. TOT ORG CARBON MG/L           0.0000       0.0000       0.0000      0.0000       0.0000
 14. CONDUCTIVITY  MMMHO/CM    10767.4400     -13.2115       0.0047     39.7095       0.6625
 16. HARDNESS      MG/L          -62.0267      17.4877      -0.0994    225.9448       0.5801
 17. SODIUM        MG/L           24.5229       0.7788      -0.0001      9.7503       0.8765


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR      UNITS            A0           A1      STANDARD      CORR.
NO.                                                         ERROR        COEFF.

  1. TOTAL BIOMASS MIL C/ML        0.4991       0.4368      0.1386      0.1627
  2. VIABLE BIOMASSMIL C/ML        0.5888      -0.0187      0.2187      0.2195
  5. RES CHLORINE  MG/L
  6. TURBIDITY-SIO2MG/L            0.6498       0.3921      0.1924      0.6007
  9. TOT ORG CARBONMG/L            0.4867       0.3918      0.1338      0.3444
 10. AMMONIA       MG/L            0.5383       0.5188      0.0985      0.3331
 12. PH            PH              0.4175       0.5013      0.0146      0.5083
 13. TOT ORG CARBON MG/L           0.0000       0.0000      0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM        2.3402       0.2615      0.0141      0.3987
 16. HARDNESS      MG/L            1.6019       0.6234      0.1936      0.6405
 17. SODIUM        MG/L            0.9933       0.4992      0.0572      0.8911
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 3

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS           A0          A1      STANDARD     CORR.      SAMPLE
NO.                                                       ERROR      COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML      3.3430      0.0874      1.4879      0.5586        25
  2. VIABLE BIOMASSMIL C/ML      0.3298      0.1526      1.4017      0.4579        23
  5. RES CHLORINE  MG/L          1.6131      0.4895      0.5464      0.7148        12
  6. TURBIDITY-SIO2MG/L          6.6513      0.2639      3.3534      0.6462        26
  9. TOT ORG CARBONMG/L         -2.7798      1.0950      2.9308      0.9079        24
 10. AMMONIA       MG/L          1.3432      0.9323      2.1068      0.8852        26
 12. PH            PH            4.0190      0.4827      0.2050      0.5878        26
 13. TOT ORG CARBON MG/L         0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM    781.2891      0.5063     38.8259      0.6634        26
 16. HARDNESS      MG/L        186.0314      0.2609     42.1757      0.8545        20
 17. SODIUM        MG/L          5.5744      0.8723      6.5898      0.9544        26


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS           A0          A1          A2       STANDARD     CORR.
NO.                                                                    ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML      4.5214     -0.0994      0.0069      1.4851      0.5609
  2. VIABLE BIOMASSMIL C/ML     -1.2665      0.9166     -0.0733      1.3779      0.4861
  5. RES CHLORINE  MG/L         -9.5261      3.1930     -0.1616      0.5220      0.7440
  6. TURBIDITY-SIO2MG/L          0.8685      0.7494     -0.0080      2.8465      0.7618
  9. TOT ORG CARBONMG/L          5.8906      0.1242      0.0223      2.6303      0.9266
 10. AMMONIA       MG/L         -7.9944      1.9241     -0.0251      2.0338      0.8935
 12. PH            PH            9.6816     -1.1183      0.1130      0.2047      0.5896
 13. TOT ORG CARBON MG/L         0.0000      0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM  -4240.3360      7.3229     -0.0023     35.3925      0.7312
 16. HARDNESS      MG/L        196.4859      0.2132      0.0000     42.1078      0.8550
 17. SODIUM        MG/L         13.9686      0.6963      0.0009      6.4879      0.9558


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS           A0          A1      STANDARD     CORR.
NO.                                                       ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML      0.3067      0.2949      0.1171      0.6740
  2. VIABLE BIOMASSMIL C/ML     -0.7506      0.9139      0.3430      0.8209
  5. RES CHLORINE  MG/L          0.0499      0.7642      0.0439      0.7284
  6. TURBIDITY-SIO2MG/L         -0.1160      0.9029      0.1703      0.7740
  9. TOT ORG CARBONMG/L         -0.1568      1.0838      0.1120      0.8087
 10. AMMONIA       MG/L          0.0272      0.9779      0.0479      0.9006
 12. PH            PH            0.4770      0.4638      0.0122      0.5801
 13. TOT ORG CARBON MG/L         0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM      1.6072      0.4976      0.0109      0.6751
 16. HARDNESS      MG/L          1.4465      0.3948      0.0598      0.8316
 17. SODIUM        MG/L          0.1406      0.9130      0.0403      0.9446
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR      UNITS              A0           A1      STANDARD     CORR.      SAMPLE
NO.                                                           ERROR       COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML         1.8380       0.0285      0.3862      0.3859        24
  2. VIABLE BIOMASSMIL C/ML         2.2026      -0.1636      4.3792      0.0704        20
  5. RES CHLORINE  MG/L            -0.8772       0.7158      0.5363      0.8032        12
  6. TURBIDITY-SIO2MG/L             6.9656       0.3402      4.2803      0.6551        25
  9. TOT ORG CARBONMG/L            -1.3786       0.8975      3.3424      0.8446        23
 10. AMMONIA       MG/L             1.1453       0.9215      2.7227      0.8338        23
 12. PH            PH               5.8548       0.2435      0.1913      0.3151        25
 13. TOT ORG CARBON MG/L            0.0000       0.0000      0.0000      0.0000         0
 14. CONDUCTIVITY  MMMHO/CM       553.2649       0.6677     37.6827      0.7463        25
 16. HARDNESS      MG/L           189.8890       0.2341     68.5445      0.6699        19
 17. SODIUM        MG/L            10.0335       0.8232     10.4907      0.8249        25


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR      UNITS              A0           A1           A2        STANDARD     CORR.
NO.                                                                          ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML         2.8246      -0.1273       0.0058       0.3784      0.4279
  2. VIABLE BIOMASSMIL C/ML         0.2988       0.7930      -0.0940       4.3628      0.1113
  5. RES CHLORINE  MG/L             1.0455       0.2492       0.0279       0.5356      0.8038
  6. TURBIDITY-SIO2MG/L            -2.3901       1.1068      -0.0124       3.2801      0.8153
  9. TOT ORG CARBONMG/L            13.0369      -0.7083       0.0368       2.5456      0.9131
 10. AMMONIA       MG/L           -10.4850       2.1577      -0.0312       2.6279      0.8462
 12. PH            PH              39.1935      -9.1771       0.6646       0.1779      0.4702
 13. TOT ORG CARBON MG/L            0.0000       0.0000       0.0000       0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM     -3137.0260       5.7205      -0.0017      36.2035      0.7688
 16. HARDNESS      MG/L           169.9953       0.3246      -0.0000      68.3870      0.6718
 17. SODIUM        MG/L            44.7336      -0.1132       0.0058       9.8897      0.8462


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR      UNITS              A0           A1      STANDARD     CORR.
NO.                                                           ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML         0.2077       0.1215      0.0616      0.4716
  2. VIABLE BIOMASSMIL C/ML        -1.0195       0.2221      0.8317      0.7968
  5. RES CHLORINE  MG/L            -0.3951       1.1925      0.0520      0.7748
  6. TURBIDITY-SIO2MG/L            -0.1989       1.0062      0.1724      0.7923
  9. TOT ORG CARBONMG/L             0.1177       0.8040      0.1224      0.6907
 10. AMMONIA       MG/L            -0.0298       1.0127      0.0752      0.8194
 12. PH            PH               0.6929       0.2195      0.0111      0.3044
 13. TOT ORG CARBON MG/L            0.0000       0.0000      0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM         1.1618       0.6391      0.0105      0.7504
 16. HARDNESS      MG/L             1.4945       0.3695      0.0961      0.6852
 17. SODIUM        MG/L             0.1641       0.8995      0.0660      0.8413
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR      UNITS           A0          A1       STANDARD     CORR.       SAMPLE
NO.                                                         ERROR      COEFF.       SIZE

  1. TOTAL BIOMASS MIL C/ML       2.2167      0.0216      0.2994      0.5217         23
  2. VIABLE BIOMASSMIL C/ML       0.5772      0.0467      2.5703      0.0602         23
  5. RES CHLORINE  MG/L           0.3930     -0.0136      0.0374      0.9989         11
  6. TURBIDITY-SIO2MG/L          -0.7085      0.2328      1.8161      0.8141         24
  9. TOT ORG CARBONMG/L          -0.7940      0.3658      2.8268      0.6224         22
 10. AMMONIA       MG/L           2.0925      0.7741      2.7142      0.7877         23
 12. PH            PH             3.0646      0.6145      0.1909      0.6511         24
 13. TOT ORG CARBON MG/L          0.0000      0.0000      0.0000      0.0000          0
 14. CONDUCTIVITY  MMMHO/CM     509.6621      0.7013     36.8547      0.7733         24
 16. HARDNESS      MG/L         155.7979      0.0961     27.6299      0.7601         18
 17. SODIUM        MG/L          10.9695      0.8009     10.7789      0.8154         24


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR      UNITS           A0          A1          A2       STANDARD     CORR.
NO.                                                                     ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML       3.1408     -0.1243      0.0054      0.2902      0.5626
  2. VIABLE BIOMASSMIL C/ML      -1.0417      0.9186     -0.0949      2.5428      0.1574
  5. RES CHLORINE  MG/L           1.5570     -0.2971      0.0170      0.0333      0.9992
  6. TURBIDITY-SIO2MG/L           3.9642     -0.1527      0.0062      1.1584      0.9289
  9. TOT ORG CARBONMG/L          -0.3872      0.3204      0.0010      2.8261      0.6226
 10. AMMONIA       MG/L          -8.8655      1.9388     -0.0294      2.6299      0.8023
 12. PH            PH             6.1831     -0.2665      0.0621      0.1908      0.6516
 13. TOT ORG CARBON MG/L          0.0000      0.0000      0.0000      0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM  -2753.1370      5.1679     -0.0015     35.6451      0.7899
 16. HARDNESS      MG/L         169.0051      0.0369      0.0000     27.4604      0.7635
 17. SODIUM        MG/L          33.5860      0.1874      0.0038     10.5266      0.8248


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR      UNITS           A0          A1       STANDARD     CORR.
NO.                                                         ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML       0.2744      0.1095      0.0492      0.5633
  2. VIABLE BIOMASSMIL C/ML      -0.7399      0.0270      0.4541      0.8257
  5. RES CHLORINE  MG/L          -0.1395     -0.4561      0.0619      0.9947
  6. TURBIDITY-SIO2MG/L          -0.2507      0.6411      0.1599      0.7011
  9. TOT ORG CARBONMG/L          -1.2575      1.5629      0.2774      0.7133
 10. AMMONIA       MG/L          -0.0111      0.9623      0.0793      0.7920
 12. PH            PH             0.3715      0.5865      0.0113      0.6499
 13. TOT ORG CARBON MG/L          0.0000      0.0000      0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM       1.0670      0.6695      0.0102      0.7793
 16. HARDNESS      MG/L           1.7095      0.2247      0.0643      0.7425
 17. SODIUM        MG/L           0.0625      0.9481      0.0728      0.8353
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 1 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS            A0          A1       STANDARD     CORR.     SAMPLE
NO.                                                        ERROR      COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML       2.4286      0.0057      0.7544     0.0261       25
  2. VIABLE BIOMASSMIL C/ML       0.5551     -0.0354      0.8085     0.0831       25
  5. RES CHLORINE  MG/L           1.0010      0.1767      0.5307     0.4555       12
  6. TURBIDITY-SIO2MG/L           2.1193      0.0499      0.8998     0.5176       26
  9. TOT ORG CARBONMG/L          -0.7105      0.3246      2.4291     0.6689       24
 10. AMMONIA       MG/L           2.9179      0.7134      3.4269     0.6664       26
 12. PH            PH             4.4236      0.3916      0.1563     0.5766       26
 13. TOT ORG CARBON MG/L          0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM     462.6919      0.7392     37.0176     0.8183       26
 16. HARDNESS      MG/L         213.9470      0.1758     64.7749     0.6015       20
 17. SODIUM        MG/L           4.6733      0.8464     13.1874     0.8393       26


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS            A0          A1          A2      STANDARD     CORR.
NO.                                                                    ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML       2.3784      0.0136     -0.0003      0.7544     0.0266
  2. VIABLE BIOMASSMIL C/ML       0.3801      0.0550     -0.0092      0.8076     0.0956
  5. RES CHLORINE  MG/L           2.6574     -0.2253      0.0240      0.5301     0.4572
  6. TURBIDITY-SIO2MG/L           1.8429      0.0731     -0.0004      0.8958     0.5238
  9. TOT ORG CARBONMG/L          -3.4259      0.6286     -0.0070      2.3951     0.6803
 10. AMMONIA       MG/L         -13.6726      2.4756     -0.0446      3.2848     0.6995
 12. PH            PH           -15.3731      5.9886     -0.3950      0.1508     0.6155
 13. TOT ORG CARBON MG/L          0.0000      0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM   -1345.3860      3.1935     -0.0008     36.5685     0.8232
 16. HARDNESS      MG/L         235.4631      0.0775      0.0000     64.5876     0.6046
 17. SODIUM        MG/L         -10.1003      1.1563     -0.0015     13.0300     0.8435


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS            A0          A1       STANDARD     CORR.
NO.                                                        ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML       0.3594      0.0241      0.0950     0.1275
  2. VIABLE BIOMASSMIL C/ML      -0.7432      0.1417      0.4289     0.5506
  5. RES CHLORINE  MG/L          -0.1612      0.5910      0.1019     0.3660
  6. TURBIDITY-SIO2MG/L           0.0235      0.3571      0.1213     0.5506
  9. TOT ORG CARBONMG/L          -1.7363      1.9194      0.3056     0.7697
 10. AMMONIA       MG/L           0.0329      0.9194      0.0898     0.7250
 12. PH            PH             0.5235      0.3925      0.0095     0.5827
 13. TOT ORG CARBON MG/L          0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM       0.9669      0.7019      0.0102     0.8232
 16. HARDNESS      MG/L           1.7220      0.2823      0.0893     0.6457
 17. SODIUM        MG/L          -1.6722      1.8126      0.1704     0.8842
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 3 TO SAMPLE SOURCE 4

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR      UNITS             A0          A1      STANDARD     CORR.      SAMPLE
NO.                                                         ERROR      COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML        1.4825      0.1814      0.4308      0.6894         26
  2. VIABLE BIOMASSMIL C/ML        2.1965     -0.3403      4.3135      0.1642         20
  5. RES CHLORINE  MG/L           -1.1561      1.0997      0.3923      0.9001         12
  6. TURBIDITY-SIO2MG/L           -0.8133      1.1865      3.0353      0.8597         27
  9. TOT ORG CARBONMG/L            1.0620      0.8187      2.1861      0.9367         23
 10. AMMONIA       MG/L           -0.2101      1.0079      2.1912      0.9094         25
 12. PH            PH              4.5456      0.4101      0.1694      0.5302         27
 13. TOT ORG CARBON MG/L           0.0000      0.0000
 14. CONDUCTIVITY  HMMHO/CM      -69.2825      1.0552     35.2253      0.8327         27
 16. HARDNESS      MG/L           86.1121      0.7481     67.1114      0.6826         21
 17. SODIUM        MG/L           -0.2174      0.9954      6.6542      0.9280         27


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR      UNITS             A0          A1.         A2      STANDARD     CORR.
NO.                                                                     ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        1.9323      0.0279      0.0105      0.4264      0.6971
  2. VIABLE BIOMASSMIL C/ML        3.9831     -3.5435      0.4621      4.1490      0.3159
  5. RES CHLORINE  MG/L           -3.5428      1.9964     -0.0824      0.3896      0.9016
  6. TURBIDITY-SIO2MG/L            1.1836      0.6664      0.0260      2.9837      0.8648
  9. TOT ORG CARBONMG/L            5.6462      0.2713      0.0117      1.8998      0.9526
 10. AMMONIA       MG/L           -4.2357      1.4497     -0.0114      2.1763      0.9106
 12. PH            PH             96.3222    -24.7216      1.7181      0.1040      0.8538
 13. TOT ORG CARBON MG/L           0.0000      0.0000      0.0000
 14. CONDUCTIVITY  HMMHO/CM    -3380.8910      5.4029     -0.0014     34.7280      0.8378
 16. HARDNESS      MG/L          351.8313     -0.9942      0.0026     63.0509      0.7271
 17. SODIUM        MG/L            6.7226      0.8115      0.0012      6.6173      0.9292


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR      UNITS             A0          A1      STANDARD     CORR.
NO.                                                         ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        0.1063      0.3920      0.0669      0.6761
  2. VIABLE BIOMASSMIL C/ML       -0.8075      0.1437      0.8653      0.7604
  5. RES CHLORINE  MG/L           -0.2526      1.2684      0.0310      0.9264
  6. TURBIDITY-SIO2MG/L            0.0402      0.9904      0.1386      0.8861
  9. TOT ORG CARBONMG/L            0.2258      0.7542      0.0832      0.8707
 10. AMMONIA       MG/L           -0.0668      1.0479      0.0585      0.8975
 12. PH            PH              0.5451      0.3848      0.0099      0.5135
 13. TOT ORG CARBON MG/L           0.0000      0.0000
 14. CONDUCTIVITY  MMMHO/CM       -0.2084      1.0668      0.0096      0.8542
 16. HARDNESS      MG/L            0.8481      0.6599      0.1022      0.6178
 17. SODIUM        MG/L           -0.0941      1.0463      0.0362      0.9512
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 4 TO SAMPLE SOURCE 5

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA     SENSOR      UNITS            A0          A1       STANDARD     CORR.      SAMPLE
NO.                                                        ERROR       COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML        0.6734      0.8467      0.7023      0.5897        25
  2. VIABLE BIOMASSMIL C/ML        0.3715      0.4039      2.2611      0.6278        19
  5. RES CHLORINE  MG/L            0.3910     -0.0213      0.0365      0.9990        11
  6. TURBIDITY-SIO2MG/L            2.2639      0.1534      2.8736      0.3060        26
  9. TOT ORG CARBONMG/L            0.0821      0.3813      2.6261      0.6865        22
 10. AMMONIA        MG/L          -0.0045      0.9035      1.1309      0.9729        25
 12. PH             PH             1.0376      0.8411      0.1993      0.6460        26
 13. TOT ORG CARBON MG/L           0.0000      0.0000      0.0000      0.0000         0
 14. CONDUCTIVITY   MMMHO/CM      43.8441      0.9748     11.7912      0.9829        26
 16. HARDNESS       MG/L          70.7664      0.4888     54.8072      0.6409        20
 17. SODIUM         MG/L           2.2242      0.9583      4.4833      0.9683        26


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA     SENSOR      UNITS            A0          A1          A2       STANDARD     CORR.
NO.                                                                    ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML       -1.0246      2.0872     -0.2083      0.7000      0.5933
  2. VIABLE BIOMASSMIL C/ML       -0.7707      9.1430     -0.5868      1.2495      0.9027
  5. RES CHLORINE  MG/L            0.6211     -0.1131      0.0089      0.0358      0.9990
  6. TURBIDITY-SIO2MG/L            4.0480     -0.2579      0.0172      2.8181      0.3581
  9. TOT ORG CARBONMG/L           -3.2669      0.8127     -0.0098      2.5426      0.7102
 10. AMMONIA        MG/L           5.5373      0.2603      0.0172      0.9995      0.9789
 12. PH             PH            57.6275    -14.1809      0.9962      0.1947      0.6661
 13. TOT ORG CARBON MG/L           0.0000      0.0000      0.0000      0.0000      0.0000
 14. CONDUCTIVITY   MMMHO/CM     635.6782      0.2088      0.0002     11.7127      0.9831
 16. HARDNESS       MG/L         -65.2204      1.3909     -0.0014     53.5722      0.6611
 17. SODIUM         MG/L          -8.4839      1.2352     -0.0017      4.2808      0.9711


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA     SENSOR      UNITS            A0          A1       STANDARD     CORR.
NO.                                                        ERROR       COEFF.

  1. TOTAL BIOMASS MIL C/ML        0.1810      0.6430      0.0765      0.6212
  2. VIABLE BIOMASSMIL C/ML       -0.2780      0.3841      0.4545      0.8190
  5. RES CHLORINE  MG/L           -0.2672     -0.4083      0.0609      0.9949
  6. TURBIDITY-SIO2MG/L            0.2594      0.2997      0.1892      0.4928
  9. TOT ORG CARBONMG/L           -0.8577      1.3388      0.2729      0.7243
 10. AMMONIA        MG/L           0.0013      0.9639      0.0371      0.9603
 12. PH             PH             0.1146      0.8585      0.0116      0.6482
 13. TOT ORG CARBON MG/L           0.0000      0.0000      0.0000      0.0000
 14. CONDUCTIVITY   MMMHO/CM       0.1531      0.9524      0.0034      0.9639
 16. HARDNESS       MG/L           0.6990      0.6592      0.0859      0.7178
 17. SODIUM         MG/L          -0.0991      1.0474      0.0226      0.9841
```

```
REGRESSION ANALYSIS FOR APR  1, 1979 TO APR 30, 1979

FROM SAMPLE SOURCE 5 TO SAMPLE SOURCE 6

LINEAR CURVE FIT RESULTS (Y=A0 + A1*X)

CHA      SENSOR      UNITS             A0          A1      STANDARD     CORR.      SAMPLE
NO.                                                          ERROR      COEFF.      SIZE

  1. TOTAL BIOMASS MIL C/ML        2,3367      0,0635      0,7519     0,0734        25
  2. VIABLE BIOMASSMIL C/ML        0,4752     -0,0357      0,8203     0,1221        24
  5. RES CHLORINE  MG/L            2,6216     -0,1379      0,4649     0,6191        12
  6. TURBIDITY-SIO2MG/L            2,2284      0,2031      0,8870     0,5688        26
  9. TOT ORG CARBONMG/L            0,2702      0,8203      2,9208     0,8031        23
 10. AMMONIA       MG/L            2,8271      0,7911      2,6146     0,8298        25
 12. PH            PH              2,8453      0,5864      0,1193     0,7927        26
 13. TOT ORG CARBON MG/L           0,0000      0,0000
 14. CONDUCTIVITY  MMMHO/CM       18,9414      0,9921      8,3018     0,9920        26
 16. HARDNESS      MG/L           88,3779      0,9619     49,6581     0,8124        20
 17. SODIUM        MG/L          -16,2452      1.1733      5.0115     0.9735        26


PARABOLIC CURVE FIT RESULTS (Y=A0 + A1*X + A2*X**2)

CHA      SENSOR      UNITS             A0          A1          A2      STANDARD     CORR.
NO.                                                                      ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        0,2835      1,2166     -0,1315      0,7384     0,2019
  2. VIABLE BIOMASSMIL C/ML        0,4939     -0,1099      0,0060      0,8193     0,1314
  5. RES CHLORINE  MG/L            3,8472     -4,7053      0,5389      0,4349     0,6784
  6. TURBIDITY-SIO2MG/L            0,6361      0,7716     -0,0313      0,7454     0,7227
  9. TOT ORG CARBONMG/L            2,1875      0,0606      0,0416      2,6564     0,8405
 10. AMMONIA       MG/L            1,3610      0,9711     -0,0051      2,6093     0,8306
 12. PH            PH            -53,7068     15,8588     -1,0298      0,0818     0,9085
 13. TOT ORG CARBON MG/L           0,0000      0,0000      0,0000
 14. CONDUCTIVITY  MMMHO/CM     -130,5771      1,1849     -0,0001      8,2946     0.9920
 16. HARDNESS      MG/L         -215,3994      3,3954     -0,0043     39,5101     0,8859
 17. SODIUM        MG/L          -28,2577      1,5076     -0,0022      4,7545     0.9761


LOGARITHMIC CURVE FIT RESULTS (LOG(Y)=A0 +A1*LOG(X))

CHA      SENSOR      UNITS             A0          A1      STANDARD     CORR.
NO.                                                          ERROR      COEFF.

  1. TOTAL BIOMASS MIL C/ML        0,3074      0,1901      0,0930     0,2305
  2. VIABLE BIOMASSMIL C/ML       -0,7790     -0,1638      0,4275     0,5604
  5. RES CHLORINE  MG/L            0,3133     -0,1627      0,0805     0,6665
  6. TURBIDITY-SIO2MG/L            0,1936      0,4746      0,1119     0,6720
  9. TOT ORG CARBONMG/L            0,0599      0,7195      0,3391     0,7357
 10. AMMONIA       MG/L            0,1730      0,8417      0,0684     0,8587
 12. PH            PH              0,3170      0,6205      0,0071     0,8059
 13. TOT ORG CARBON MG/L           0,0000      0,0000
 14. CONDUCTIVITY  MMMHO/CM        0,0072      0,9983      0,0023     1.0019
 16. HARDNESS      MG/L            0,5872      0,8064      0,0627     0,8526
 17. SODIUM        MG/L           -2,1592      2,1096      0,0767     0,9629
```

```
LOG-NORMAL DISTRIBUTION: SEP  3, 1980 TO FEB 28, 1981

                          ONE              LOG(Y)=F(Z)            CHI       SAMPLE
          AVERAGE        SIGMA         SLOPE      INTERCEPT      SQUARE      SIZE
FLASH MIX PH

             10.8          0.9      0.4223E -1  0.1032E  1  291.7720      149
PLANT FLOW

              1.4          0.3      0.1010E  0  0.1385E  0  189.0946      148
SLUDGE DENSITY

              0.9          0.9      0.3121E  0 -0.1451E  0   36.5369      149
SLUDGE PUMP

            738.4        139.7      0.2065E  0  0.2849E  1  212.8979      147
LIME FEED VL.

             73.1        237.2      0.5289E  0  0.1444E  1   63.7471       87
EOF..
```

APPENDIX B

STANFORD/WMS DATA FOR ORGANIC REMOVAL BY GAC

This section contains data relative to the performance of activated carbon with age for removal of TOC and trace organics.

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF TOC

I- Influent Concentration, mg/l; O- Effluent Concentration, mg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	6.44	1.46	0.227	0.92	0.143	5.56	0.863	2.65	.411	10.2	5.9	0.578		6.1
600	7.29	1.46	0.200	1.06	0.145	5.61	0.770	2.71	.372	10.6	5.4	0.509		4.9
900	9.74	1.20	0.123	2.78	0.285	6.68	0.685	3.55	.365	9.3	4.7	0.505		4.7
1240	8.08	2.02	0.250	2.15	0.266	6.86	0.849	3.68	.455	9.5	4.3	0.453		3.6
1580	10.80	3.31	0.306	2.45	0.227	6.15	0.569	3.97	.368	11.2	4.8	0.429		5.0
1835														
2090	6.52	2.81	0.431	2.50	0.383	8.98	1.377	4.76	.731					
2430	6.21	2.71	0.436	2.69	0.433	4.92	0.792	3.44	.554					
3235	9.87	5.67	0.574			8.20	0.831							
3660	9.25	4.67	0.505	5.12	0.554	6.52	0.705	5.44	.588					
4125	12.60	7.19	0.571	6.46	0.513	8.27	0.656	7.31	.580					
4465	11.90	7.08	0.595	6.61	0.555	10.50	0.882	8.06	.678					
4800														
5225	7.92	6.46	0.816	5.32	0.672	7.33	0.926	6.37	.804					
5525	8.61	6.38	0.741	7.18	0.834	7.24	0.841	6.93	.805					
6000	8.64	5.75	0.666	5.01	0.580	7.88	0.912	6.21	.719	9.3	6.3	0.677	15.1	6.0
6300	8.02	4.84	0.603	5.82	0.726	7.00	0.873	5.89	.734	8.8	5.9	0.670	18.0	5.7
6600		4.27		5.02						7.4	7.1	0.959	12.5	5.1
6900	6.77	7.15	1.056	5.83	0.861	6.82	1.007	6.6	.975	6.6	5.9	0.894	11.4	5.4
7100	9.15	5.54	0.605	5.28	0.577	7.41	0.810	6.08	.664	10.9	3.5	0.321	10.8	4.5
7820	8.93	5.05	0.566	5.44	0.609	5.69	0.637	5.39	.604	9.0	6.1	0.678	10.5	4.6
8400	8.24	4.33	0.525	5.07	0.615	6.17	0.749	5.19	.630	6.7	4.0	0.597	8.7	3.7
8820	6.73	4.11	0.611	4.22	0.627	4.97	0.738	4.43	.659	6.7	3.7	0.552	8.9	3.3
9400	7.14	4.80	0.672	6.04	0.846	4.91	0.688	5.25	.735	6.8	3.6	0.529	9.8	3.8

PERFORMANCE OF GRANULAR ACTIVATED CARBON FOR REMOVAL OF CHLOROFORM

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	11.24	0.20	0.018	0.32	0.028	12.13	1.079	4.1	0.375					
600	12.06	0.82	0.068	0.26	0.022	12.88	1.068	4.7	0.386	15.8	9.2	0.582		
900	14.58	0.41	0.028	1.13	0.078	15.18	1.041	5.6	0.382	19.5	9.6	0.492		
1240	17.57	0.86	0.049	1.90	0.108	18.12	1.031	7.0	0.396					
1580	22.11	2.79	0.126	6.42	0.290	19.79	0.895	9.7	0.437	20.7	11.1	0.536		
1835	16.56	4.68	0.283	11.43	0.690	17.26	1.042	11.1	0.007					
2090	9.21	4.80	0.521	5.86	0.636	11.50	1.249	7.4	0.802					
2430	10.21	10.23	1.002	8.78	0.860	9.34	0.915	9.5	0.926					
3235	11.69	8.13	0.695			13.85	1.185							
3660	12.67	21.17	1.671	30.75	2.427	15.59	1.230	22.5	1.776	23.2	28.7	1.237		29.1
4125	4.98	16.02	3.217	14.18	2.847	7.93	1.592	12.71	2.552	16.9	28.2	1.669		27.5
4465	6.24	12.05	1.931	9.62	1.542	5.27	0.845	9.0	1.439	16.3	23.1	1.417		19.8
4800	3.82	6.99	1.830	6.63	1.736					16.5	20.8	1.261		20.4
5225	6.93	13.15	1.898	12.69	1.831					16.1	20.7	1.286	18.4	24.8
5525	4.42	15.60	3.529	15.49	3.505									
5825	10.33	15.54	1.504	14.28	1.382					12.0	17.6	1.467	14.0	16.3
6100	8.85	15.26	1.724	14.88	1.681					21.0	26.4	1.257	19.6	22.8
6600	4.88	8.44	1.730	7.79	1.596					18.2	19.9	1.093	22.7	20.0
6900	7.45	10.45	1.403	10.54	1.415					16.8	17.3	1.030	21.0	20.1
7100	8.75	15.21	1.738	14.10	1.611									
7820														16.4
8400										17.9	24.7	1.380	12.9	26.1
8820										10.1	19.3	1.911	10.6	22.0
9400														

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF TRICHLOROETHANE

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	10.78	0.04	0.004	0.04	0.004	12.27	1.138	4.12	.382					
600	22.02	0.19	0.009	0.04	0.002	19.44	0.883	6.56	.298	10.9	2.1	0.193		
900	24.32	0.00	0.000	0.07	0.003	22.73	0.935			10.6	2.4	0.226		
1240	61.15	0.03	0.000	0.22	0.004	38.55	0.630	12.93	.212					
1580	64.69	0.20	0.003	1.94	0.030	42.21	0.652	14.78	.229	26.4	4.2	0.159		
1835	98.08	0.43	0.004	5.71	0.058	55.34	0.564	20.49	.209					
2090	15.79	0.47	0.030	1.93	0.122	21.74	1.377	8.05	.510					
2430	15.31	3.62	0.236	3.64	0.238	15.09	0.986	7.45	.487					
3235	37.82	5.35	0.141			0.17	1.133							
3660	31.32	21.60	0.690	36.45	1.164	37.70	1.204	31.92	1.019	63.5	19.9	0.313		15.9
4125	5.01	17.62	3.517	16.04	3.202	15.60	3.114	16.42	3.277	5.7	13.9	2.439		14.0
4465	9.98	14.28	1.431	12.76	1.279	7.54	0.756	11.53	1.155	13.6	13.3	0.978		12.3
4800	2.46	6.98	2.837	7.37	2.996					5.1	9.0	1.765		9.4
5225	0.23	15.67	68.130	15.38	66.870					1.0	6.1	6.1	4.5	7.5
5525	0.17	19.54	114.941	22.36	131.529									
5825	1.01	15.68	15.525	15.06	14.911					0.8	5.6	7.0	5.2	4.8
6100	0.98	15.66	15.980	16.22	16.551					0.6	6.6	11.0	2.1	7.6
6600	0.42	8.57	20.405	8.06	19.190					0.4	4.9	12.25	1.2	5.4
6900	0.48	8.11	16.896	8.02	16.708					0.6	3.3	5.5	2.0	3.4
7100	5.54	15.59	2.814	13.85	2.500									
7820														5.1
8400										0.4	4.0	10.0	1.5	3.8
8820										0.4	2.7	6.75	1.9	3.2
9400														

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF BROMODICHLOROMETHANE

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	2.67	0.00	0.000	0.00	0.000	1.70	0.637							
600	4.14	0.00	0.000	0.00	0.000	2.98	0.720			7.6	3.5	0.461		
900	5.51	0.00	0.000	0.01	0.002	3.93	0.713			10.3	4.5	0.437		
1240	4.34	0.00	0.000	0.05	0.012	4.41	1.016							
1580	4.46	0.02	0.004	0.29	0.065	4.39	0.984	1.57	.351	6.1	4.0	0.656		
1835	3.45	0.30	0.087	0.71	0.206	3.70	1.072	1.57	.455					
2090	1.60	0.07	0.044	0.31	0.194	2.07	1.294	.82	.510					
2430	1.87	0.39	0.209	0.47	0.251	1.71	0.914	.86	.458					
3235	1.59	0.54	0.340			2.27	1.428							
3660	2.34	2.21	0.944	3.64	1.556	2.57	1.098	2.81	1.199	8.3	8.0	0.964		8.7
4125	1.82	1.77	0.973	1.57	0.863	1.51	0.830	1.62	.888	7.4	7.7	1.041		8.4
4465	2.06	1.65	0.801	1.51	0.733	1.16	0.563	1.44	.699	7.5	7.1	0.947		6.8
4800	1.77	1.03	0.582	1.19	0.672			1.11	.627	8.8	8.3	0.943		8.3
5225	8.26	2.75	0.333	2.78	0.337			2.77	.335	9.4	8.8	0.936	11.2	9.0
5525	3.68	4.00	1.087	5.06	1.375			4.53	1.231					
6000	11.21	5.81	0.518	6.40	0.571			6.11	.545	7.0	11.1	1.586	8.3	9.7
6300	8.97	5.95	0.663	7.97	0.889			6.96	.776	20.4	12.8	0.627	14.3	14.2
6600	4.63	3.92	0.847	4.83	1.043			4.38	.945	15.7	11.0	0.701	21.0	11.9
6900	6.04	3.82	0.632	4.61	0.763			4.22	.698	12.0	9.6	0.800	17.9	11.6
7100	5.80	8.81	1.519	8.12	1.400			8.46	1.459					
7820														
8400														13.7
8820										23.2	22.6	0.974	16.5	20.4
9400										15.7	21.5	1.369	12.7	19.5

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF TRICHLOROETHYLENE

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	3.14	0.00	0.000	0.00	0.000	1.64	0.522							
600	23.24	0.04	0.002	0.00	0.000	4.85	0.209			18.8	2.1	0.112		
900	12.55	0.00	0.000	0.00	0.000	4.94	0.394			9.0	2.2	0.244		
1240	9.72	0.00	0.000	0.03	0.003	6.32	0.650				2.5			
1580	19.02	0.29	0.015	0.75	0.039	7.18	0.377	2.74	.144	11.9	2.1	0.176		
1835	28.27	0.00	0.000	0.12	0.004	8.10	0.287							
2090	8.36	0.00	0.000	0.00	0.000	4.33	0.518							
2430	4.13	0.00	0.000	0.00	0.000	2.96	0.717							
3235	8.00	0.00	0.000			5.60	0.700							
3660	5.93	0.00	0.000	0.00	0.000	4.90	0.826			10.7	2.6	0.243		2.1
4125	1.80	0.30	0.167	0.55	0.306	3.49	1.939	1.45	.804	4.6	2.5	0.543		2.3
4465	3.02	0.26	0.086	0.55	0.182	1.61	0.533	.81	.267	6.6	2.3	0.348		1.8
4800	0.58	0.23	0.397	0.49	0.845			.36	.621	2.3	2.3	1.0		1.9
5225	0.09	0.67	7.444	1.03	11.444			.85	9.444	1.1	1.6	1.455	2.7	1.6
5525	0.10	1.22	12.200	2.40	24.000			1.81	18.1					
6000	0.00	1.24		1.95						1.1	1.6	1.455	2.3	1.4
6300	0.00	1.22		2.35						1.0	1.9	1.9	2.0	1.9
6600	0.00	0.73		1.35						0.9	1.7	1.889	1.8	1.6
6900	0.04	0.72	18.000	1.15	28.750			.935	23.375	1.0	1.5	1.5	1.8	1.4
7100	2.32	0.00	0.000	2.61	1.125									
7820														
8400														2.1
8820										0.7	1.9	2.714	1.5	2.0
9400										0.7	1.6	2.286	1.9	1.6

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF DIBROMOCHLOROMETHANE

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	1.11	0.00	0.000	0.00	0.000	0.44	0.396							
600	3.37	0.00	0.000	0.00	0.000	0.16	0.344			5.5	1.8	0.327		
900	5.04	0.00	0.000	0.00	0.000	1.79	0.355			8.3	2.8	0.337		
1240	2.85	0.00	0.000	0.00	0.000	2.25	0.789							
1580	2.11	0.00	0.000	0.07	0.033	2.09	0.991			4.2	2.1	0.5		
1835	1.46	0.00	0.000	0.19	0.130	1.85	1.267							
2090	0.63	0.00	0.000	0.13	0.206	1.47	2.333							
2430	0.86	0.08	0.093	0.19	0.221	0.72	0.837	.33	.384					
3235	0.79	0.10	0.127			1.01	1.278							
3660	1.28	0.43	0.336	0.91	0.711	1.09	0.852	.81	.633	3.3	2.0	0.606		9.8
4125	1.35	0.40	0.296	0.43	0.319	0.74	0.548	.52	.388	4.3	2.6	0.605		3.1
4465	1.21	0.42	0.347	0.48	0.397	0.60	0.496	.50	.413	4.9	3.5	0.714		1.7
4800	1.27	0.32	0.252	0.54	0.425			.43	.339	3.8	3.8	1.0		3.0
5225	7.33	1.03	0.141	1.08	0.147			1.06	.144	3.6	2.7	0.75	4.7	2.8
5525	2.95	1.80	0.610	2.22	0.753			2.01	.681					
6000	10.89	2.65	0.243	3.17	0.291			2.91	.267	2.4	5.5	2.292	3.9	3.3
6300	7.69	2.77	0.360	4.52	0.588			3.65	.474	11.7	3.5	0.299	7.2	5.1
6600	4.26	2.12	0.498	3.09	0.725			2.61	.612	6.8	2.6	0.382	9.8	3.7
6900	6.51	2.07	0.318	2.91	0.447			2.49	.382	4.3	2.5	0.581	8.7	3.4
7100	6.28	5.62	0.895	6.79	1.081			6.21	.988					
7820														8.4
8400										16.9	11.8	0.698	11.8	14.6
8820										8.1	8.8	1.086	5.8	11.4
9400														

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF TETRACHLOROETHYLENE

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	6.03	0.02	0.003	0.03	0.005	1.32	0.219	.46	.076					
600	13.79	0.19	0.014	0.10	0.007	2.13	0.154	.81	.058	15.6	4.8	0.308		
900	20.19	0.13	0.006	0.07	0.003	2.42	0.120	.87	.043	17.0	4.5	0.265		
1240	37.42	0.04	0.001	0.06	0.002	3.75	0.100	1.28	.034		3.2			
1580	73.81	0.11	0.001	0.40	0.005	5.73	0.078	2.08	.028	47.4	6.4	0.135		
1835	103.85	0.29	0.003	0.17	0.002	10.69	0.103	3.72	.036					
2090	27.72	0.12	0.004	0.11	0.004	6.58	0.237	2.27	.082					
2430	14.13	0.39	0.028	0.23	0.016	4.33	0.306	1.65	.117					
3235	18.96	0.05	0.003			6.06	0.320							
3660	7.70	0.06	0.008	0.27	0.035	4.85	0.630	1.73	.224	11.9	4.9	0.412		3.8
4125	1.65	0.24	0.145	0.32	0.194	4.20	2.545	1.59	.962	4.1	4.0	0.976		4.0
4465	2.66	0.05	0.019	0.15	0.056	1.38	0.519	.53	.198	9.5	4.2	0.442		3.3
4800	0.29	0.07	0.241	0.27	0.931					3.1	3.6	1.161		3.6
5225	0.00	0.11		0.24						2.4	2.9	1.208	2.8	3.0
5525	0.09	0.33	3.667	0.54	6.000									
6000	0.23	0.28	1.217	0.51	2.217					2.6	3.0	1.154	4.4	3.0
6300	0.38	0.30	0.789	0.73	1.921					1.9	2.3	1.211	3.5	2.6
6600	0.39	0.22	0.564	0.46	1.179					1.2	1.7	1.417	1.6	1.9
6900	0.21	0.22	1.048	0.34	1.619					1.4	1.6	1.143	2.3	1.6
7100	2.08	0.89	0.428	1.40	0.673									
7820														1.3
8400										2.5	2.7	1.08	2.1	2.4
8820										4.5	4.2	0.933	4.5	4.0
9400														

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF BROMOFORM

I- Influent Concentration, µ g/l; O- Effluent Concentration, µg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON		AVERAGE		WMS DATA				
										GAC			PLANT	
	I	O	O/I	O	O/I	O	O/I	O	O/I	I	O	O/I	I	O
300	0.56	0.02	0.036	0.00	0.000	0.13	0.232							
600	1.99	0.00	0.000	0.00	0.000	0.32	0.161			12.8	10.0	0.781		
900	3.48	0.00	0.000	0.00	0.000	0.73	0.210			19.7	10.3	0.523		
1240	1.44	0.00	0.000	0.00	0.000	1.01	0.701							
1580	0.30	0.00	0.000	0.00	0.000	0.84	2.800			7.6	9.8	1.289		
1835	0.35	0.00	0.000	0.05	0.143	0.71	2.029							
2090	0.14	0.00	0.000	0.03	0.214	0.36	2.571							
2430	0.17	0.74	4.353	0.64	3.765	0.43	2.529	0.60	3.549					
3235	0.39	0.00	0.000			0.46	1.179							
3660	0.55	0.07	0.127	0.22	0.400	0.36	0.655	0.22	0.394	8.5	9.6	1.129		9.8
4125	0.55	0.00	0.000	0.13	0.236	0.34	0.618	0.16	0.285	8.6	8.6	1.0		6.8
4465	0.00	0.00		0.08		0.14		0.07						4.0
4800	0.55	0.11	0.200	0.00	0.000									3.9
5225	2.98	0.22	0.074	0.12	0.040			0.17	0.057	2.9	3.5	1.207	3.0	1.9
5525	1.05	0.34	0.324	0.42	0.400			0.38	0.362					
6000	2.84	0.51	0.180	0.54	0.190			0.53	0.185	0.3	3.8	12.667	2.5	0.4
6300	2.13	0.46	0.216	0.94	0.441			0.70	0.329	1.2	0.0	0	0.6	0.2
6600	1.15	0.36	0.313	0.59	0.513			0.48	0.413	1.0	0.0	0	0.3	0.0
6900	1.77	0.39	0.220	0.55	0.311			0.47	0.266	0.1	0.1	1.0	0.2	0.0
7100	0.23	0.20	0.870	0.25	1.087			0.23	0.978					
7820														0.3
8400										0.1	1.8	18.0	0.0	0.1
8820										0.0	0.0	0	0.1	0.0
9400														

PERFORMANCE OF GRANULAR ACTIVATED CARBON FOR REMOVAL OF ETHYLBENZENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	45	115	2.556	70	1.556	85	1.889
600	325	35	0.108	35	0.108	95	0.292
900	125	15	0.120	20	0.160	110	0.880
1240	240	105	0.438	25	0.104	130	0.542
1580	55	35	0.636	45	0.818	250	4.545
1835	90	120	1.333	45	0.500	150	1.667
2090	25	25	1.000	0	0.000	35	1.400
2430	135	25	0.185	0	0.000	20	0.148
3235	60	130	2.167			95	1.583
3660	35	0	0.000	30	0.857	30	0.857
4125	80	35	0.438	0	0.000	45	0.563
4465	75	50	0.667	30	0.400	25	0.333
4800	65	45	0.692	35	0.538		
5225	200	40	0.200	230	1.150		
5525	60			235	3.917		
6000	220	110	0.500	40	0.182		
6300	245	175	0.714	80	0.327		
6600	510	75	0.147	145	0.284		
6900	270	125	0.463	60	0.222		
7100	360	155	0.431	135	0.375		
9400	135	25	0.185	50	0.370		

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF CHLOROBENZENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	215	100	0.465	9	0.042	475	2.209
600	885	130	0.147	170	0.192	245	0.277
900	270	25	0.093	45	0.167	535	1.981
1240	1840	295	0.160	100	0.054	390	0.212
1580	1190	180	0.151	120	0.101	1015	0.853
1835	1005	390	0.388	105	0.104	560	0.557
2090	135	100	0.741	40	0.296	200	1.481
2430	730	120	0.164	45	0.062	160	0.219
3235	1550	345	0.223			480	0.310
3660	120	50	0.417	60	0.500	185	1.542
4125	300	125	0.417	125	0.417	270	0.900
4465	295	150	0.508	135	0.458	190	0.644
4800	190	165	0.868	80	0.421		
5225	260	120	0.462	220	0.846		
5525	195			255	1.308		
6000	345	235	0.681	60	0.174		
6300	315	345	1.095	245	0.778		
6600	890	510	0.573	135	0.152		
6900	525	575	1.095	295	0.562		
7100	9405	2050	0.218	580	0.062		
9400	445	230	0.517	385	0.865		

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF 1, 3 DICHLOROBENZENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
	I	O	O/I	O	O/I	O	O/I
300	1315	35	0.027	15	0.011	215	0.163
600	1610	50	0.031	20	0.012	190	0.118
900	4945	0	0.000	70	0.014	180	0.036
1240	4095	70	0.017	20	0.005	80	0.020
1580	4015	20	0.005	15	0.004	295	0.073
1835	5930	100	0.017	25	0.004	180	0.030
2090	135	0	0.000	25	0.185	110	0.815
2430	1965	25	0.013	0	0.000	250	0.127
3235	905	0	0.000			215	0.238
3660	445	20	0.045	20	0.045	145	0.326
4125	620	20	0.032	30	0.048	195	0.315
4465	275	15	0.055	50	0.182	160	0.582
4800	165	200	1.212	150	0.909		
5225	1575	75	0.048	250	0.159		
5525	1980			325	0.164		
6000	375	210	0.560	50	0.133		
6300	585	160	0.274	100	0.171		
6600	575	40	0.070	95	0.165		
6900	610	640	1.049	90	0.148		
7100	1183	195	0.165	30	0.025		
9400	130	60	0.462	95	0.731		

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF 1, 4 DICHLOROBENZENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
	I	O	O/I	O	O/I	O	O/I
300	2010	15	0.007	65	0.032	190	0.095
600	2815	345	0.123	70	0.025	190	0.067
900	5070	0	0	105	0.021	145	0.029
1240	4545	165	0.036	55	0.012	195	0.043
1580	4415	55	0.012	50	0.011	330	0.075
1835	6820	100	0.015	35	0.005	245	0.036
2090	200	40	0.200	30	0.150	205	1.025
2430	3760	30	0.008	40	0.011	470	0.125
3235	2075	15	0.007			365	0.176
3660	1280	0	0	20	0.016	230	0.180
4125	2095	20	0.010	50	0.024	310	0.148
4465	835	0	0	100	0.120	290	0.347
4800	490	199	0.406	340	0.694		
5225	820	210	0.256	175	0.213		
5525	750			320	0.427		
6000	2075	220	0.106	285	0.137		
6300	3025	135	0.045	210	0.069		
6600	3175	445	0.140	210	0.066		
6900	1525	490	0.321	95	0.062		
7100	6344	0	0	240	0.038		
9400	475	20	0.042	45	0.095		

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF 1, 2 DICHLOROBENZENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	2220	30	0.014	30	0.014	260	0.117
600	4800	45	0.009	40	0.008	230	0.048
900	7890	15	0.002	175	0.022	270	0.034
1240	6510	45	0.007	35	0.005	240	0.037
1580	4655	60	0.013	75	0.016	535	0.115
1835	6840	75	0.011	30	0.004	390	0.057
2090	230	25	0.109	60	0.261	225	0.978
2430	2420	45	0.019	50	0.021	480	0.198
3235	1410	25	0.018			410	0.291
3660	1170	15	0.013	55	0.047	270	0.231
4125	3140	55	0.018	100	0.032	365	0.116
4465	1325	25	0.019	125	0.094	330	0.249
4800	590	70	0.119	180	0.305		
5225	430	90	0.209	80	0.186		
5525	325			80	0.246		
6000	1520	40	0.026	95	0.063		
6300	2745	0	0	80	0.029		
6600	3030	155	0.051	70	0.023		
6900	210	235	1.119	50	0.238		
7100	3906	610	0.156	200	0.051		
9400	585	50	0.085	100	0.171		

PERFORMANCE OF GRANULAR ACTIVATED CARBON FOR REMOVAL OF 1, 2, 4 TRICHLOROBENZENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
	I	O	O/I	O	O/I	O	O/I
300	17290	625	0.036	610	0.035	1295	0.075
600	12590	85	0.007	50	0.004	655	0.052
900	12160	50	0.004	1010	0.083	550	0.045
1240	16180	95	0.006	50	0.003	365	0.023
1580	18190	105	0.006	70	0.004	1060	0.058
1835	44345	105	0.002	60	0.001	705	0.016
2090	220	365	1.659	545	2.477	1080	4.909
2430	7495	60	0.008	195	0.026	1050	0.140
3235	4020	85	0.021			945	0.235
3660	7420	90	0.012	70	0.009	1015	0.137
4125	10660	50	0.005	370	0.035	675	0.063
4465	4685	70	0.015	595	0.127	815	0.174
4800	3105	100	0.032	135	0.043		
5225	1090	95	0.087	155	0.142		
5525	1095			85	0.078		
6000	5440	810	0.149	255	0.047		
6300	4840	65	0.013	165	0.034		
6600	8655	190	0.022	140	0.016		
6900	7840	385	0.049	75	0.010		
7100	7439	75	0.010	190	0.026		
9400	2045	50	0.024	120	0.059		

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF NAPHTHALENE AND 1, 2, 3 TRICHLOROBENZENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
	I	O	O/I	O	O/I	O	O/I
300	9725	475	0.049	480	0.049	665	0.068
600	7865	75	0.010	115	0.015	435	0.055
900	7320	65	0.009	1095	0.150	435	0.059
1240	4990	70	0.014	245	0.049	380	0.076
1580	3950	150	0.038	140	0.035	635	0.161
1835	7930	35	0.004	20	0.003	405	0.051
2090	1305	260	0.199	1365	1.046	1500	1.149
2430	1880	165	0.088	345	0.184	470	0.250
3235	2335	50	0.021			390	0.167
3660	3560	50	0.014	345	0.097	470	0.132
4125	5845	15	0.003	155	0.027	395	0.068
4465	1335	45	0.034	115	0.086	435	0.326
4800	1460	15	0.010	20	0.014		
5225	235	25	0.106	50	0.213		
5525	250			40	0.160		
6000	680	280	0.412	65	0.096		
6300	530	1280	2.415	40	0.075		
6600	845	250	0.296	20	0.024		
6900	560	1485	2.652	15	0.027		
7100	1124	410	0.365	85	0.076		
9400	2515	35	0.014	20	0.008		

PERFORMANCE OF GRANULAR ACTIVATED CARBON FOR REMOVAL OF HEPTALDEHYDE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	40	80	2.000	105	2.625	0	0
600	0	0		0		55	
900	140	40	0.286	75	0.536	0	0
1240	80	0	0	110	1.375	80	1.000
1580	85	75	0.882	65	0.765	435	5.118
1835	160	20	0.125	15	0.094	215	1.344
2090	35	15	0.429	0	0	0	0
2430	205	120	0.585	80	0.390	0	0
3235	40	35	0.875			45	1.125
3660	50	50	1.000	135	2.700	40	0.800
4125	130	115	0.885	135	1.038	55	0.423
4465	0	30		85		0	
4800	240	35	0.146	25	0.104		
5225	1910	50	0.026	265	0.139		
5525	370			345	0.932		
6000	180	190	1.056	75	0.417		
6300	150	220	1.467	130	0.867		
6600	1445	160	0.111	200	0.138		
6900	1530	0	0	140	0.092		
7100	0						
9400	0						

PERFORMANCE OF GRANULAR ACTIVATED CARBON FOR REMOVAL OF P-XYLENE

I- Influent Concentration, g/l; 0- Effluent Concentration, g/l; 0/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	80	60	0.750	0	0	115	1.438
600	95	35	0.368	25	0.263	100	1.053
900	60	0	0	0	0	105	1.750
1240	55	95	1.727	0	0	75	1.364
1580	50	30	0.600	30	0.600	220	4.400
1835	75	120	1.600	35	0.467	120	1.600
2090	30	30	1.000	0	0	40	1.333
2430	55	35	0.636	0	0	30	0.545
3235	125	50	0.400			90	0.720
3660	60	0	0	35	0.583	30	0.500
4125	65	30	0.462	35	0.538	50	0.769
4465	35	40	1.143	25	0.714	0	0
4800	85	20	0.235	0	0		
5225	55	0	0	135	2.455		
5525	30			95	3.167		
6000	65	40	0.615	20	0.308		
6300	0	75		45			
6600	0	120		80			
6900	190	70	0.368	65	0.342		
7100				220			
9400	70	55	0.786	80	1.143		

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF M-XYLENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
	I	O	O/I	O	O/I	O	O/I
300	155	270	1.742	105	0.677	440	2.839
600	360	105	0.292	90	0.250	295	0.819
900	50	25	0.500	20	0.400	350	7.000
1240	185	390	2.108	25	0.135	235	1.270
1580	90	80	0.889	95	1.056	695	7.722
1835	110	315	2.864	100	0.909	460	4.182
2090	70	65	0.929	15	0.214	125	1.786
2430	135	110	0.815	15	0.111	75	0.556
3235	320	95	0.297			310	0.969
3660	215	55	0.256	100	0.465	105	0.488
4125	180	75	0.417	35	0.194	180	1.000
4465	150	120	0.800	60	0.400	135	0.900
4800	120	40	0.333	25	0.208		
5225	75			275	3.667		
5525	70			185	2.643		
6000	110	60	0.545	35	0.318		
6300	105	95	0.905	100	0.952		
6600	215	65	0.302	175	0.814		
6900	200	80	0.400	115	0.575		
7100	490	665	1.357	500	1.020		
9400	175	65	0.371	125	0.714		

PERFORMANCE OF GRANULAR ACTIVATED CARBON FOR REMOVAL OF 2-METHYL NAPHTHALENE

I- Influent Concentration, ng/l; O- Effluent Concentration, ng/l; O/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	130	0	0	0	0	0	0
600	75	30	0.400	0	0	50	0.667
900	100	15	0.150	45	0.450	40	0.400
1240	105	40	0.381	165	1.571	225	2.143
1580	130	0	0	0	0	55	0.423
1835	135	30	0.222	20	0.148	90	0.667
2090	0						
2430	365	170	0.466			25	0.068
3235	40						
3660	0						
4125	40						
4465	0						
4800	0						
5225	265			90	0.340		
5525	185						
6000	315	280	0.889	95	0.302		
6300	80	100	1.250	30	0.375		
6600	85	20	0.235	30	0.353		
6900	0	155					
7100	75	105	1.400	25	0.333		
9400	95	40	0.421				

PERFORMANCE OF GRANULAR ACTIVATED CARBON FOR REMOVAL OF 1-METHYL NAPHTHALENE

I- Influent Concentration, ng/l; O- Effluent Concentration, n g/l; O/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	80	0	0	0	0	0	0
600	45	30	0.667	0	0	25	0.556
900	90	0	0	55	0.611	60	0.667
1240	120	25	0.208	50	0.417	50	0.417
1580	115	0	0	0	0	110	0.957
1835	70	0	0	0	0	40	0.571
2090	0	0		0		0	
2430	385	170	0.442	0	0	15	0.039
3235	45	0	0			0	0
3660	0	0		0		0	
4125	80	0	0	0	0	0	0
4465	20	0	0	0	0	0	0
4800	0	40		0			
5225	290	0	0	115	0.397		
5525	85			0	0		
6000	365	475	1.301	130	0.356		
6300	80	135	1.688	65	0.813		
6600	160	65	0.406	40	0.250		
6900	0	205		0			
7100	485	355	0.732	65	0.134		
9400	85	15	0.176	0	0		

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF TOTAL ORGANIC HALOGEN - TOX

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES		NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
	I	O	O/I	O	O/I	O	O/I
300	160.0	50.0	.313	56.9	.356	142.0	.888
600	204.0	35.6	.175	38.0	.186	149.0	.730
900	294.0	113.0	.384	60.2	.205	167.0	.568
1240	263.0	116.0	.441	97.3	.370	172.0	.654
1580	316.0	75.4	.239	133.0	.421	187.0	.592
1835	400.0	38.7	.097	123.0	.308	222.0	.555
2090	276.0	58.4	.212	47.3	.171	139.0	.504
2430	147.0	38.0	.259	59.9	.407	130.0	.884
3235	112.0					158.0	1.411
3660	150.0	70.6	.471	64.6	.431	172.0	1.147
4125	121.0	90.5	.748	105.0	.868	115.0	.950
4465	144.0	102.0	.708	100.0	.694	90.8	.631
4800	105.0	148.0	1.410	111.0	1.057		
5225	147.0	72.3	.492	85.5	.582		
5525	151.0	66.5	.440	83.0	.550		
6000	111.0	66.0	.595	79.3	.714		
6300	93.4	68.1	.729	117.0	1.253		
6600	86.5	91.7	1.060	73.2	.846		
6980	91.1	64.3	.706	76.6	.841		
7100							
9400							

PERFORMANCE OF GRANULAR ACTIVATED CARBON
FOR REMOVAL OF PURGABLE ORGANIC HALOGEN - POX

I- Influent Concentration, μg/l; O- Effluent Concentration, μg/l; O/I- Fractional Concentration

BEDVOLUMES	I	NEW CARBON		REGENERATED CARBON		EXHAUSTED CARBON	
		O	O/I	O	O/I	O	O/I
300	98.4	6.2	.063	4.2	.043	75.1	.763
600	129.0	23.1	.179	21.1	.164	112.0	.868
900	187.0	94.1	.503	38.3	.205	116.0	.620
1240	173.0	104.0	.601	93.1	.538	117.0	.676
1580	191.0	5.6	.029	107.0	.560	118.0	.618
1835	210.0	5.6	.027	77.5	.369	139.0	.662
2090	99.2	6.1	.061	3.4	.034	79.8	.795
2430	81.1	13.0	.160	15.5	.191	65.2	.804
3235	33.6					83.7	2.491
3660	93.6	30.1	.322	27.1	.290	40.3	.431
4125	34.0	38.1	1.121	45.6	1.341	46.0	1.353
4465	40.0	33.3	.833	38.8	.970	28.6	.715
4800	23.3	26.7	1.146	31.3	1.343		
5225	30.9	24.9	.806	25.9	.838		
5525	16.4	30.4	1.854	31.9	1.945		
6000	29.8	31.8	1.067	32.0	1.074		
6300	28.0	29.6	1.057	26.4	.943		
6600	22.2	45.4	2.045	23.4	1.054		
6980	19.3	19.4	1.005	18.6	.964		
7100							
9400							

APPENDIX C

PLANT DOWNTIME AND MAINTENANCE LOG

This section contains a chronological listing of equipment problems experienced during the test period.

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $
Feb 4 to 7	72 (4)		Calcium carbonate deposits on 24" delivery line from flash mixer to flocculator reduced the flow capacity to 0.7 MGD. The deposits were partially removed by soaking in 36% inhibited hydrochloric acid for 22 hours.		72 *							3650
Feb 17 to 21	91 (4, 5,7)		The softened deposits were later removed by hydroflushing (high pressure water cleaning)	5	75 *	29 *		11 *			44	
Feb 9 to 20			Calcium carbonate deposits on recarbonation mixer turbine caused unbalance and excessive vibration. Deposits were removed.			187 (mixer)						
Feb 9	6 (3)		Computer maintenance	6 *							6	
Feb 10	8 (3)		Computer maintenance	8 *							7	
Feb 23	5 (3)		Computer maintenance	5 *							5	

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $
Dec 3			Ozonizer repair								50	
Dec 4			Ozonizer repair									
Dec 1 to 9			Water jacket leak in ozonizer				208					
			Computer maintenance	4							25	
Dec 24	9 (4)		Aerator sump pump flush		9 *		9				7	
Dec 28 to 30	40 (3)		Flash mixer clean-up to remove encrusted calcium carbonate		40 *		72					
Jan 1 to 4			Ozonizer down				33					
Jan 5 to 11			Lime system maintenance								14	
Jan 12 to 18			Lime system maintenance								22	
Jan 19 to 25	5 (2)	5 *	Lime system maintenance Ozonizer system maintenance Influent dye test				52				18	
Jan 26 to 31	5 (3)		Lime system maintenance	5 *							14	

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $
Nov 3	5		Power out								9	
Nov 4			Flushed lime slaker and lime slurry feed tank; computer maintenance		3						13	
Nov 5			Computer maintenance Lime system maintenance Recarbonation maintenance								21 24	
Nov 6			Computer maintenance Lime system maintenance Aeration system maintenance									
Nov 6 to 30			Tube failed in ozonizer				552					
Nov 11			Inspect ozonizer								1	
Nov 12			Remove ozonizer dielectric tube and wash unit								8	
Nov 13	14 (4)		Aerator sump pump frozen		14 *						6	
Nov 14	15 (4)		Aerator sump pump frozen		12 *							
Nov 16 to 30			General maintenance								85	
Nov 26	3 (3)			3 *							1	

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $
Oct 12 to 13			Ozonizer inspected				48				3	
Oct 14	2 (3)		Computer maintenance	2 *			24					
Oct 15							24					
Oct 16	2 (3)		Computer power supply failure	1 *			10					
Oct 20			Tightened stack gas compressor belts			1					4	
Oct 23			Changed oil - lime clarifier reservoir		4						2	
Oct 24	1 (3)		Computer maintenance	1 *								
Oct 27			Computer maintenance								12	
Oct 28			Computer maintenance								11	
Oct 29			Computer maintenance		2						13	
Oct 30			Computer maintenance								9	
Oct 31			Computer maintenance								8	

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $	
Sep 12			Recarbonation system maintenance			10					5		
Sep 15			Calibrated pit probe								2		
Sep 16			Maintenance on furnace controls lockouts; cleaned stack gas filter								2		
Sep 16 to 20			Disassembled ozonizer and cleaned tubes				99				34		
Sep 21			Replaced belt on dewatering screw drive motor								1		
Sep 22			Replaced bolt on dewatering screw								2		
Sep 23	1 (3)		Computer maintenance	1 *									
Sep 25			Repair lime conveyor								10		
Sep 30	2 (2)		Repair lime mixer	2 *							4		
			Computer maintenance										
Oct 2			Lime bin vibrator belts								2		
Oct 8 to 11	1 (4)		Ozonizer out of service; dryer solenoid valve not working		1 *		82						

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $
Aug 19	4 (3)		Computer maintenance	4 *								
Aug 21			Sludge furnace down		12 5(5)	12 (4) 5					4	
Aug 22			Sludge furnace down		11(5)	11					4	
Aug 26	5 (3)		Computer / new facility interface 1300 - 1900	5 *							4	
Aug 27	5 (3)		Computer maintenance 1200 - 1430	5 *							4	
Aug 28	3 (3)		Computer maintenance 1330 - 1700	3 *								
Aug 29	6 (3)		Computer maintenance 1130 - 1700	6 *								
Sep 2	9 (3)		Computer maintenance 1000 - 1830	9 *								
Sep 8			Computer maintenance								4	
Sep 9			Flushed lime slurry feed tank		14	14 (4)						
Sep 10			Furnace maintenance calibrated pit probe		24	24 (4)					2	
Sep 11			Tightened stack gas compressor belts		11	11 (4) 10					6	

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $
Jul 26	3 (2)	3 *										
Jul 28	2		Computer maintenance	2 *								
Jul 31	1		Aerator sump pump frozen		3 *						6	
Aug 2	7 (2)	7 *	Aerator sump pump frozen - down 0430 - 1100		7						6	
Aug 5	1 (3)		Computer maintenance	1 *	2							
Aug 6	3 (2)	3 *			1	3	1					
Aug 7			Computer maintenance								4	
Aug 8 to 11	91 (4)		Aerator sump pump frozen		91 *						38	
Aug 12	18 (4)		Removed and started cleaning aerator sump pump valve. (Modified flow pattern implemented 8-12-80 through 8-21-80)		18 * 6	6 (4)					9	
Aug 13	3 (3)		Computer maintenance	3 *							3	
Aug 13 to 20			Repair aerator sump pump and associated valves		192	192 (4)					50	

PLANT DOWNTIME AND MAINTENANCE LOG

* Equipment or Process Causing Plant Shutdown
(#) Number of Process Causing Downtime

Date	Plant Shutdown (1)	Influent Unavailable (2)	Problem Description	Computer (3)	Chemical Clarification (4)	Recarbonation (5)	Ozonation (6)	Filters (7)	Carbon Adsorption (8)	Chlorination (9)	Maintenance Manhours	Material $
Jul 1	3 (2)	3 *	Replaced lime slurry feed pump mechanical seal - on line at 1900		19						8	
Jul 2			Computer maintenance								4	
Jul 8	4											
Jul 13	3											
Jul 14	3 (2)	3 *										
Jul 16					8							
Jul 17	20 (2)	20 *	Down 0400 - 2400		1							
Jul 18	8 (2)	8 *										
Jul 21	3 (2)	3 *	Ozonizer maintenance				3				4	
Jul 22			Tightened stack gas compressor belts. Down 1300 - 1400			1					2	
Jul 23	3 (2)	3 *										
Jul 24	13 (4)		Recarbonation maintenance. Aerator sump pump frozen by calcium carbonate deposits		8 (5) 13 *	8					13	
Jul 25					13 (5)	13					6	

APPENDIX D

WMS COSTS

This section contains operating and maintenance costs incurred by each sensor/subsystem in the WMS during the test period. A list of recommended spares is also included.

Sample Collection and Distribution System

The following expenditures can be expected for 8 months of continuous operation:

1)	50 Stainless Steel Filter Screens	$ 66.00
2)	Pneumatic Cylinder	45.00
3)	Pump Boots	20.00
4)	Pump Parts	66.00
5)	Drive Belts	12.50
6)	Red Valves	62.50
7)	Pressure Transducers	165.00
8)	Red Valves Sleeves (4)	120.00
	Total =	$557.00

Recommended Spares:

1) 50 Stainless Steel Filters (10)
2) Pressure Gages (1)
3) Pump Boots (4)
4) Monyo Pump (1)
5) Drive Belts (2)
6) Red Valves (1)
7) Pressure Transducer (1)
8) Red Valve Sleeves (4)
9) Pneumatic Back Flushing Cylinder (1)

The only major hardware components to fail during the test period were Red Valves, one Monyo pump, and one pneumatic cylinder. As such, it is not yet possible to estimate the life expectancy of the system except to state that it should be at least 4 years.

During the course of the test period, 7 man-hours were spent for scheduled maintenance and 9.75 man-hours for unscheduled maintenance.

Commercial Sensors

Total Organic Carbon

The following expenditures can be expected for 8 months of continuous operation:

1) Phosphoric Acid	$125.00
2) Pump Tubing	33.00
3) Sample Pump	250.00
4) Persulfate	744.00
5) U.V. Lamps (3)	540.00
6) Filters	33.00
Total =	$1725.00

Recommended Spares:

1) Sample Pump (1)
2) Reagent Pump (1)
3) U.V. Chamber Pump (1)
4) U.V. Lamps (3)
5) Pump Tubing
6) Fiberfax Filter (Mist Filter) (1 lb.)

The overall life of the analyzer has yet to be determined. During the course of the test period 32.0 man-hours were spent on routine maintenance and 11.5 man-hours on unscheduled maintenance.

Hardness Analyzer

The following expenditures can be expected for 8 months of continuous operation:

1) Bromide Electrodes	$ 175.00
2) Copper Electrodes	273.00
3) #113201 Reagent (21.45 Gal.)	1393.00
4) Pump Tubes (3 sets)	90.00
5) Calcium Carbonate	7.00
6) Ammonium Hydroxide	3.00
7) Hydrochloric Acid	3.00
Total =	$1946.00

Recommended Spares:

1) Pump Tubes (2 sets)
2) Bromide Electrode (1)
3) Copper Electrode (1)

The overall life of the analyzer has yet to be determined. However, the apparent life expectancy of several of the components has been determined:

1) Electrodes - 6 months
2) Pump Tubes - 3 months
3) Flow Cell - 2 years

During the course of the test period, 67.75 man-hours were spent on routine maintenance and 4.75 man-hours on unscheduled maintenance.

Nitrate Analyzer

The following expenditures can be expected for 8 months of continuous operation:

1) Phosphoric Acid	$329.00
2) Marshals Reagent	327.00
3) Sulfanilamide	198.00
4) Poppet Valves	30.00
5) Cadmium	50.00
6) Potassium Nitrate	8.00
7) Ammonium Acetate	10.00
8) Acetic Acid	10.00
Total =	$962.00

Spares

1) Poppet Valves (4)
2) Metricone Drive w/ Motor (1)
3) Pump Bellows (1)
4) Pump Motor (1)
5) Diaphragms (Air Pump) (2)

The overall life expectancy of the analyzer has yet to be determined. However, the apparent life expectancy of several components has been determined.

1) Metricone - 2 years
2) Pump Motor - 3 years
3) Pump Poppet Valves - 6 months

During the course of the test period, 19.5 man-hours were spent on scheduled maintenance and 22.0 man-hours on unscheduled maintenance.

pH Analyzer

The only operating cost incurred during operation will be $50.00 for standards. It is recommended that a spare electrode be kept on hand. The estimated life expectancy of the electrode is 3 years. During the course of the test period, 2.0 man-hours were spent on routine maintenance and 1.0 man-hour on unscheduled maintenance.

Residual Chlorine Analyzer

The following expenditures can be expected for 8 months of continuous operation:

1) Redox Electrodes	$150.00
2) Iodine Electrodes	150.00
3) #112501 Reagent	456.00
4) #112502 Reagent	456.00
5) Residual Chlorine Standard	19.80
6) Pump Tube Sets (3)	150.00
Total =	$1381.80

Recommended Spares:

1) Pump Tubes (2 sets)
2) Redox Electrode (1)
3) Iodine Electrode (1)

The overall life expectancy of the analyzer has yet to be determined. However, the apparent life expectancy of several of the components has been determined:

1) Electrodes - 6 months
2) Pump Tubes - 3 months
3) Temperature Controlled Flow Cell - 3 years

During the course of the test period, 50.75 man-hours were spent on routine maintenance and 2.25 man-hours on unscheduled maintenance.

Sodium Analyzer

The following expenditures can be expected for 8 months of continuous operation:

1) Sodium Electrode (1)	$165.00
2) Reference Electrode (1)	42.00
3) Anhydrous Ammonia (1 cyl.)	45.00
4) Sodium Chloride (3.3 lbs.)	14.52
5) Reference Electrode Electrolyte	15.00
Total =	$281.52

Recommended Spares:

1) Sodium Electrode (1)
2) Reference Electrode (1)

The overall life expectancy of the analyzer has yet to be determined. However, the life expectancy of the reference electrode is approximately 1 year.

During the course of the test period, 70.00 man-hours were spent on scheduled maintenance and 13.5 man-hours on unscheduled maintenance.

Temperature Sensor

The following expenditure can be expected for 8 months of continuous operation of the two temperature sensors.

Action Pac electronics module (1)	$125.00

The only recommended spare is 1 Action Pac electronics module.

The life expectancy of the sensor has yet to be determined. During the course of the test period, .5 man-hour was spent on scheduled maintenance and .5 on unscheduled maintenance.

Turbidity

The following expenditures can be expected for 8 months of continuous operation of the Sigrist Model UP52-TJ Photometer:

1) Chart Paper (2 rolls)	$32.00
2) Light Source (2)	15.00
3) Glow Lamp (1)	9.50
Total =	$56.50

Recommended Spares:

1) Chart Paper (1 roll)
2) Light Sources (2)

Since there have been no major component failures in the Sigrist Photometer, the life expectancy has yet to be determined. During the course of the test period, 2.25 man-hours were spent on scheduled maintenance and .25 man-hour on unscheduled maintenance.

Ammonia Analyzer

The following expenditures can be expected for 8 months of continuous operation:

1) Sodium Hypochlorite	$501.00
2) Sodium Hydroxide	52.00
3) Phenol	134.00
4) Sodium Metaphosphate	7.50
5) Ammonium Chloride	4.00
6) Pump Check Valves (4)	60.00
7) Hydrochloric Acid	30.50
Total =	$789.00

Recommended Spares:

1) Metricone Drive Unit w/motor (1)
2) Pump Check Valves (4)
3) Glass Flow Cell (1)
4) Spare Pump Motor (1)
5) Pump Bellows (1)
6) Diaphragms (Air Pump) (2)

The overall life expectancy of the analyzer has yet to be determined. However, the apparent life expectancy of several of the components has been determined:

1) Metricone Assembly - 2 years
2) Pump Motor - 3 years
3) Pump Check Valves - 3-6 months

During the course of the test period, 159.75 man-hours were spent on scheduled maintenance and 18.25 man-hours on unscheduled maintenance.

Conductivity

The Beckman conductivity sensor required no consumables and suffered no part failures during the test period.

There are no recommended spares for this sensor.

During the course of the test period, .5 man-hour was spent on scheduled maintenance, and no man-hours on unscheduled maintenance.

Dissolved Oxygen Analyzer

The following expenditures can be expected for 8 months of continuous operation for the Delta Scientific unit:

1) Sodium Sulfite	$ 10.00
2) Cobalt Chloride	8.00
3) Membrane Kit (1)	42.00
4) Electrolyte	15.00
5) D.O. Test Kit	25.00
Total =	$100.00

Recommended Spares:

1) Membrane Kit (3)

The overall life expectancy of the analyzer has yet to be determined. The only significant failure which took place was the electrode. Based on this it appears the electrode's life expectancy is 4 years.

During the course of the test period, 4.0 man-hours were spent on routine maintenance and 0.5 man-hour on unscheduled maintenance.

Chemiluminescence Biosensor

Since the biosensor is a prototype unit unique to the WMS, the major initial material cost figures are presented:

1) Photometer (1)	$2,000.00
2) Peristaltic Pumps (2)	1,046.00
3) Chart Recorder (1)	700.00
4) Teflon Valves (5)	600.00
5) Air Solenoid Valves (6)	480.00
6) Flow Meters (2)	100.00
7) Tubing and Fittings	200.00
Total =	$5,126.00

The following expenditures can be expected for 8 months of continuous operation:

1) 5- Amino- 2,3- dihydro- 1,4 - phthalazinediane (12 g)	$ 30.00
2) Sodium Hydroxide (50%) (1 qt)	7.50
3) Hydrogen Peroxide (30%) (1 pt)	11.00
4) Carbon Monoxide (3 cylinders)	173.50
5) Pump Tubes (4 pks)	10.00
6) Solenoid Valves (2)	180.00
7) Valve Bushings (4)	6.00
Total =	$418.00

Recommended Spares:

1) Photomultiplier Tube (1)
2) Valve Bushings (8)
3) Teflon Valve (1)
4) Solenoid Valve (1)
5) Peristaltic Pump (1)

As there have been no major component failures, the life expectancy of the biosensor has yet to be determined.

During the course of the test period, 77.0 man-hours were spent on scheduled maintenance and 15.0 man-hours on unscheduled maintenance.

Coliform Detector

The estimated material cost for the breadboard detector is $5K.

The following expenditures can be expected for 8 months with one run a day:

1) Media (5.6 lbs)	$ 89.00
2) Platinum Electrodes (3)	255.00
3) Nitric Acid (2 pts)	45.00
4) Pump Tubes (5 pks)	33.50
5) Thermometers (5)	118.00
6) Thermistors (3)	61.00
7) Temperature Control Boards (2)	125.00
8) Electrolyte (6.6 pts)	40.00
Total =	$766.50

Recommended Spares:

1) Thermometers (5)
2) Electrodes (3)
3) Peristaltic Pump (1)
4) Teflon Valves (2)
5) Valve Bushings (10)
6) Valve Port Faces (10)
7) Solenoid Valves (2)

As yet the overall life expectancy of the coliform detector has not been determined. However, the apparent life expectancy of the electrodes appears to be 3 years. The life expectancy of the valve bushings and port faces is also 3 years.

During the course of the test period, 110.00 man-hours were spent on routine maintenance and 100.00 man-hours on unscheduled maintenance.

Gas Chromatograph

The initial cost of the WMS automated GC was $78K.

The following expenditures can be expected for 8 months of continuous operation:

1) Nitrogen Gas (2 cyl)	$130.00
2) Argon-methane Gas (3 cyl)	150.00
3) Chart Paper (4 boxes)	237.00
4) Printer Head (1)	100.00
5) Valve Bushings (2)	50.00
Total =	$667.00

Recommended Spares:

1) Preparative Column Prefilter (1)
2) Bendix Valve Bushings (2)
3) Analytical Column (1)

The useful life of the GC has yet to be determined. The instrumentation should last for many years; however, the analytical and preparative columns may require replacement more often.

During the course of the test period, 51.0 man-hours were spent on routine maintenance and 140.0 man-hours on unscheduled maintenance.

Deionized Water System

The following expenditures can be expected for 8 months of continuous operation:

1)	Rogard Filters	$ 130.00
2)	Carbon Filters	160.00
3)	Ion-Exchange Filters	475.00
4)	Reverse Osmosis Cartridge	550.00
5)	Pump Impellers (3)	16.50
6)	Sodium Hypochlorite	23.00
7)	Chlorine Filter	16.00
	Total =	$1370.50

Recommended Spares:

1) Pump Impellers (3)
2) Rogard Filters (8)
3) Carbon Filters (4)
4) Ion-Exchange Filters (8)

The useful life of the deionized water system has yet to be determined. The life expectancy of the various filters has varied significantly throughout the test period.

During the course of the test period, 10.0 man-hours were spent on routine maintenance and 3.5 man-hours on unscheduled maintenance.